SPECIAL NOTICE INSIDE

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Reliability Abstracts and Technical Reviews

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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The second section of *RATR* contains four indexes: The Subject Index is to assist in scanning or searching the literature on specific topics. The Personal Author Index identifies the publications of specific authors. The Report and Code Index is a listing of the report numbers of items abstracted and reviewed in the journal; this index also includes a listing of the ASQC codes for identifying the *RATR* accession numbers of the items to which the codes have been assigned. The Accession Number Index identifies the categories in which the abstract-reviews appear in the journal. Cumulative indexes are published annually.

EXAMPLES OF CITATIONS IN *RATR*

RATR ACCESSION NUMBER	R70-12733 ASQC 844; 413	ASQC CODES
	General Equipment Company, Banville, Calif.	CORPORATE SOURCE
TITLE	**RELIABILITY ANALYSIS OF CHECKOUT AND SUPPORT EQUIPMENT**	PUBLICATION DATE
AUTHOR	John A. Doe 23 Sep. 1968 27 p refs	
CONTRACT OR GRANT	(Contract NAS15-13411)	*TAB* AND *STAR* ACCESSION NUMBERS
REPORT NUMBER	(AD-629305; N69-15098; TR-3) Avail: CFSTI	AVAILABILITY SOURCE

RATR ACCESSION NUMBER	R70-12739 ASQC 814	ASQC CODE
TITLE	**SEMICONDUCTOR RELIABILITY.**	
	Joseph A. Smith (Eastern University, Arlington, Penn.).	AUTHOR AND AFFILIATION
JOURNAL REFERENCE	*Electric Journal,* vol. 8, Apr. 1968, p 478–492.	
	(A69-12569)	*IAA* ACCESSION NUMBER

RATR ACCESSION NUMBER	R70-12765 ASQC 773; 221; 823	ASQC CODES
TITLE	**TESTS OF SYSTEMS WITH SOME DEPENDENT FAILURES.**	
	Joseph A. Smith (Eastern University, Arlington, Penn.) and B. James White (General Equipment Company, Banville, Calif.).	AUTHORS AND AFFILIATIONS
CONFERENCE OR SYMPOSIUM REFERENCE	*Association of Reliability Engineering, Failure Rate Conference, Olney, Tex., Mar. 13–17, 1968, 8 p.*	
	Available from Assoc. of Reliability Eng., New York: $1.00	AVAILABILITY AND PRICE
IAA ACCESSION NUMBER	(A69-12407)	

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Reliability Abstracts and Technical Reviews

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81 MANAGEMENT OF RELIABILITY FUNCTION

R70-14812 ASQC 813
C-5 A RELIABILITY PROGRAM
Frank A. Stovall (Lockheed Aircraft Corp., Lockheed-Georgia Co., Reliability Engineering Dept., Marietta, Ga.) *In: Annals of Assurance Sciences; Proceedings of the Eighth Reliability and Maintainability Conference, Denver, Colo., July 7–9, 1969* Conference sponsored by the American Institute of Aeronautics and Astronautics, the Society of Automotive Engineers, and the American Society of Mechanical Engineers New York Gordon and Breach, Science Publishers, Inc. 1969 p 115–122 2 refs
(A69-36011)

Discussion of a comprehensive, yet relatively inexpensive, reliability program now in progress for the C-5A aircraft. This program is designed to attain a significant improvement in product reliability, as compared with that to be expected without the use of reliability disciplines. Stringent reliability guarantees are imposed at subsystem and system level, and tests are conducted to verify achievement. I.A.A.

Review: This is another paper on the C-5A reliability program and we can expect more in the future. It is couched in general terms, as it must be, and can provide good insight—especially to the beginner in reliability—into the kinds of things people have to do in order to insure high reliability of the final product. It can also provide others in the aircraft business with some idea of the state of the art. The paper does list some of the management techniques that are necessary, some of the problems involved with subcontractor relationships and others which are extrapolatable to almost any venture. Thus, it does provide helpful background for anyone trying to learn the business. From this paper the reader can obtain examples of contractual language used in procurement documents to ensure reliability achievement. In addition, the paper provides a list of items subjected to reliability test together with associated MTBF requirements, an abstract of a new high reliability parts program, a limited amount of information relative to reliability test cost, and a thumbnail sketch of reliability concepts and their significance. The reader without industrial experience must remember that papers such as this generally reflect a smooth untroubled flow of events and have only minor indications of difficulty and discord. This is a natural enough phenomenon, but it tends to produce in many readers a feeling that the grass must be greener on the author's side of the fence—that he is not having the kinds of troubles that we are—when in fact everyone has largely the same set of problems. It is interesting in reading a paper such as this which concerns a product about which there has been much public controversy (especially in Congress) to note that none of this is reflected in the paper.

R70-14815 ASQC 813
SURVEYOR - HARD TRIALS TO SOFT LANDINGS
M. E. Goble and D. O. Marriage (Hughes Aircraft Co., Culver City, Calif.) *In: Annals of Assurance Sciences; Proceedings of the Eighth Reliability and Maintainability Conference, Denver, Colo., July 7–9, 1969* Conference sponsored by the American Institute of Aeronautics and Astronautics, the Society of Automotive Engineers, and the American Society of Mechanical Engineers New York Gordon and Breach, Science Publishers, Inc. 1969 p 160–173
(A69-36016)

Review of the Surveyor test program and discussion of the rationale forming its basis. Flight results are compared with those obtained during testing, in particular, during solar thermal-vacuum testing. An analysis of the data obtained from seven Surveyor flights, in terms of reliability and other relevant factors, leads to the conclusion that appropriately simulated earth-based tests can yield adequate predictions of performance in a vacuum and lunar environment. I.A.A.

Review: This is a rather detailed summary of the Surveyor test program and test activities, and also indicates the rationale on which the program was based. Papers such as this which describe programs, the success of which has become a matter of record, serve a very useful purpose for those who are planning similar testing programs on future projects. It is useful to know what was done, and especially some of the difficulties involved in actually doing it. This paper is recommended reading for design and reliability engineers who have responsibility for the success of future spacecraft programs.

R70-14816 ASQC 813; 871

RELIABILITY/MAINTAINABILITY FIELD TEST EVALUATION OF FLYING CRANE HELICOPTER

C. D. Holbert (United Aircraft Corp., Sikorsky Aircraft Div., Stratford, Conn.) and R. E. Heitert (U.S. Army, Aviation Systems Command, St. Louis, Mo.) *In: Annals of Assurance Sciences; Proceedings of thd Eighth Reliability and Maintainability Conference, Denver, Colo., July 7–9, 1969* Conference sponsored by the American Institute of Aeronautics and Astronautics, the Society of Automotive Engineers, and the American Society of Mechanical Engineers New York Gordon and Breach, Science Publishers, Inc. 1969 p 174–180 1 ref

(A69-36017)

Brief discussion of an industry-government reliability/maintainability field test evaluation program for a combat fielded, cargo-carrying helicopter, the CH-54A Flying Crane. The discussion includes specific objectives, program implementation, and the results of over 12,000 flight hours of observed operation spanning a 1-year period. Present reliability, maintainability, and availability measurements experienced in two varied environments depict values derived from this program. Added usage of the data by industry and the U.S. Army for present and future planning is identified. I.A.A.

Review: This paper will be of interest largely to those in the aircraft business and in particular the helicopter business. It is essentially an historical documentary—recording what was done and what is hoped yet to be done. It gives a reasonable amount of data; some of it would discourage less hardy people in other businesses. For example there are almost two hours of maintenance time per hour of flight time. Many people will be interested in comparing the data given in the text with that for their own products. One interesting point the authors make is that the exponential distribution seems to describe the data reasonably accurately (although no indication of *goodness of fit* is given). At the end of the paper, the authors say, "All of the resulting advantages of a program of this nature have not yet been utilized or exposed. More studies are expected to come out of this initial phase of a continuing effort." The interpretation of that paragraph will vary largely with the experience the reader has had in observing large programs.

R70-14820 ASQC 810; 844

THE CREDIBILITY OF RELIABILITY MEN AND NUMBERS

R. W. Burrows (Martina Marietta Corp., Denver, Colo.) *In: Annals of Assurance Sciences; Proceedings of the Eighth Reliability and Maintainability Conference, Denver, Colo., July 7–9, 1969* Conference sponsored by the American Institute of Aeronautics and Astronautics, the Society of Automotive Engineers, and the American Society of Mechanical Engineers New York Gordon and Breach, Science Publishers, Inc. 1969 p 229–232 15 refs

The proper use of reliability predictions and analyses is discussed in terms of prediction accuracy, timeliness, the mean time before failure requirement frequently contained in proposals, and the pitfalls of numerical reliability requirements. The use of complex models is questioned. The recommendation is made that reliability engineers, in presenting their conclusions, should state their assumptions, the quantity and quality of the input data, and the uncertainties which may negate their conclusions. The results of a survey on spacecraft hardware problems are summarized. It was concluded that credibility can be protected by (1) recognizing, admitting to, and allowing for the uncertainties in reliability predictions and analyses; (2) matching the reliability analyses efforts to the tangible program benefits, and insuring proper timing; and (3) keeping abreast of specific hardware problems, and the ways of achieving reliable hardware. M.G.J.

Review: This is generally a good paper. Its cautions against having reliability be a numbers game are well taken. A reasonable fraction of reliability engineers are aware of the difficulties the author mentions. Apparently, some are not (it is to the latter group that this paper is addressed in addition to managers). It is more reasonable to show the design engineer the difficulties into which he is running rather than to tell him exactly what he must do about them. The author does both. Reliability is an engineering problem. Papers such as this which stress that fact can help improve the quality of work that reliability engineers do.

R70-14821 ASQC 815; 844

IMPACT OF SPECIFICATIONS AND STANDARDS ON THE DEVELOPMENT AND USE OF FAILURE RATES

Clifford M. Ryerson (Hughes Aircraft Co., Culver City, Calif.) *In: Annals of Assurance Sciences; Proceedings of the Eighth Reliability and Maintainability Conference, Denver, Colo., July 7–9, 1969* Conference sponsored by the American Institute of Aeronautics and Astronautics, the Society of Automotive Engineers, and the American Society of Mechanical Engineers New York Gordon and Breach, Science Publishers, Inc. 1969 p 233–237

Information is imparted in the identification of problems and the development of points of interest. Following a general introduction to the subject, sections are presented on standard part types, standardized nomenclature, standardized definitions, failure rate distributions and standard application environments. A summary conclusion presents a series of discussion topics. Author

Review: The best parts of this paper are Sections VI and VII. Section VI is a brief summary of part of the author's earlier paper in the same conference proceedings (pp. 191–198), and Section VII is a list of questions/problems with which reliability engineers need to deal and on which progress could help the reliability discipline appreciably. These questions stem from the author's long experience in the field of reliability, and experienced reliability practitioners will recognize them immediately as widespread thorny problems. Section III on standardized nomenclature tends to belabor the units in which the hazard (failure) rate is usually given. For large systems, much of the arithmetic is done on a computer and in that case, as long as the units differ by only factors of 10, there is no difficulty. A more important problem is whether the hazard rate so stated is considered to be one which is constant over many thousands of hours or one which is the *average* hazard only for the first thousand hours. Obviously, this distinction must be made, whereas the earlier one is a matter of convenient arithmetic. Section IV on standardized definitions (or more properly the lack thereof) is good. The author points out that in many cases, those who would attempt to arrive at standardized definitions merely introduce another one in the pot rather than cutting down the number of them. He makes an excellent point not often found in the literature that very often one wishes to use words such as reliability or failure in more than one way. Section V on failure rate distribution curves is unfortunately very poor, especially Part A, Engineering Implications. The author confuses failure rate ($-dR/dt$) with hazard rate ($-1/d\ln R/dt$). He also does

not make the essential distinction between MTBF and MTTF: MTBF (mean time *between* failures) applies in a repair situation whereas MTTF (mean time *to* failure) applies in a *non-repair* situation, regardless of the carelessness of engineers and other reliability practitioners in the past in using these two terms. That carelessness has caused much of the present confusion. It also points up the fact that in addition to giving a hazard rate, one should give the time interval over which it is expected to hold, and whether or not it is an average over a particular time period or truly expected to be a constant. It is recommended that those in need of enlightenment do not read this part for that purpose. Part B of Section V which discusses other distribution problems compares a Weibull with increasing hazard rate, the exponential distribution, and the Weibull with decreasing hazard rate. It is not always clear in what sense the author is using wear-out. If he using it in the sense of an increasing hazard, then some of the things he says are true by definition. If he is not using it for that, then it is not clear in what sense the author needs it. It is particularly important to realize that when one asserts". . . for stabilized parts, a zero-slope Weibull . . . distribution will apply . . ." (the author actually means the Weibull distribution with unity shape parameter), he is defining what he means by a stabilized part rather than giving a property of stabilized parts. Some reporters in the literature have implied that the decreasing hazard is observed well after the ordinary poor quality parts have been eliminated. In conclusion, if one limits his reading to sections IV, VI, and VII, he will find a very good, provocative paper.

R70-14822 ASQC 810; 844

THE IMPACT OF FAILURE DATA ON MANAGEMENT OF A LAUNCH OPERATIONS RELIABILITY PROGRAM

Robert E. Cato (NASA, Kennedy Space Center, Cocoa Beach, Fla.) and Wallace C. Wheadon (General Electric Co., Cocoa Beach, Fla) *In: Annals of Assurance Sciences; Proceedings of the Eighth Reliability and Maintainability Conference, Denver, Colo., July 7–9, 1969* Conference sponsored by the American Institute of Aeronautics and Astronautics, the Society of Automotive Engineers, and the American Society of Mechanical Engineers New York Gordon and Breach, Science Publishers, Inc. 1969 p 238–243
(A69-36022)

Discussion of efforts which have been made to conduct a responsible launch-operations reliability program with existing failure data. The basic reliability organization and requirements are discussed, and the corrective action program which is one potential source of field-failure data is reviewed. Reliability problems which occured as a result of poor data are discussed. Recovery plans to obtain acceptable field-failure data and the manner in which such data could be used to upgrade the existing program are treated. I.A.A.

Review: This paper treats an important subject and one in which the complexity can be almost overwhelming. The paper is one of a series of papers published in the R&M Annals which were prepared for continuity of presentation of a complex subject as studied and treated by various organizations. Therefore, when not studied with the other related papers in these Annals, it may be difficult for the casual reader to grasp the context of this paper as to (a) the way things used to be, (b) untested recommendations of the report, or (c) tested recommendations of the report. Without this expanded context, it may also be difficult to determine just what the recommendations were. While the term Single Failure Point is commonly used and understood by most reliability engineers, it would have been better to discuss the term sufficiently to say what it is.

R70-14828 ASQC 813

DC-10 RELIABILITY PROGRAM

H. A. Reesing (Douglas Aircraft Co., Long Beach, Calif.) *In: Annals of Assurance Sciences; Proceedings of the Eighth Reliability and Maintainability Conference, Denver, Colo., July 7–9, 1969* Conference sponsored by the American Institute of Aeronautics and Astronautics, the Society of Automotive Engineers, and the American Society of Mechanical Engineers New York Gordon and Breach, Science Publishers, Inc. 1969 p 309–314
(A69-36027)

Description of the DC-10 reliability program intended to satisfy the design objectives of passenger attractiveness, high dispatch reliability, low maintenance cost, and flight safety. Two additions to the DC-10 program are the use of computer simulation and supplier reliability guarantees. I.A.A.

Review: The important message to be gotten from this paper is that an aerospace manufacturer is able to justify, operate, and enforce a reasonably stringent reliability requirement on his suppliers. The descriptions of the procedures employed by Douglas are useful. Others in the field can compare their own practices with them; even those in other fields can see what a practical reliability program is like. It is important to notice the emphasis on reliability as an engineering problem rather than as a mathematical/statistical one. In a program such as this by a commercial organization and which has been refined over a period of years, it is reasonable to suppose that unnecessary parts of the reliability discipline have been discarded and only the most cost-effective ones retained. This is one of the things that result in the very high engineering emphasis (as opposed to a mathematical emphasis). Obviously, the engineering effort requires some of the mathematics of the reliability discipline but in general those calculations are done with a view toward fruitful effect on the product reliability rather than just on principle.

R70-14832 ASQC 812

THE STATUS OF THE INCORPORATION OF RELIABILITY TECHNIQUES INTO MECHANICAL ENGINEERING EDUCATION

C. Birnie, Jr. (Pennsylvania State Univ., Mechanical Engineering Dept., University Park, Pa.) *In: Annals of Assurance Sciences; Proceedings of the Eighth Reliability and Maintainability Conference, Denver, Colo., July 7–9, 1969* Conference sponsored by the American Institute of Aeronautics and Astronautics, the Society of Automotive Engineers, and the American Society of Mechanical Engineers New York Gordon and Breach, Science Publishers, Inc. 1969 p 392–402 3 refs

A survey was conducted to determine the current degree to which modern reliability techniques have been incorporated into mechanical engineering design. The survey results show that little progress has been made in this important area during the last three years. A number of methods are recommended for remedying this situation. Author

Review: This is an interesting paper and a worthwhile one. Faculty members should not read it uncritically, however. The old division of reliability into statistics and engineering is apparent

here, and the viewpoint one takes toward the recommendations depends largely on how he has resolved this division in his own mind. Perhaps one of the biggest problems concerning reliability vis-a-vis engineering courses in general is that engineering courses usually deal with some rather simpleminded models of (a) the motions and forces in mechanical equipment and (b) electrical signals in electrical and electronic equipment. Rarely do they treat other aspects of hardware. It is this reviewer's opinion that reliability is primarily an engineering problem and that statistics/probability is only one of the languages that engineers use to discuss and think about reliability. A great deal of reliability improvement can be accomplished, without the use of any statistics/probability, e.g., by means of failure modes and effects analyses. This is not to say that engineers should not learn something about probability/statistics but that it must compete for its own place in the already overcrowded curriculum along with other engineering subjects, more mathematics, the humanities, etc. Regardless of one's individual opinions about the exact nature of the reliability that should be taught in colleges, reliability practitioners should keep up the pressure to be sure that reliability gets its proper share of attention by educators. It certainly will not get any attention if no one pushes it from the outside.

R70-14843 ASQC 817; 871

COST-EFFECTIVE TRADE-OFFS BETWEEN MAINTENANCE PROCEDURES FOR GROUPS HAVING SEQUENTIALLY DEPLOYED SYSTEMS

J. A. Huetinck, M. Lipow, and N. R. Garner (TRW Systems Group, Redondo Beach, Calif.) *In: Proceedings of the 10th Annual West Coast Reliability Symposium, Beverly Hills, Feb. 21, 1969* Symposium sponsored by the American Society for Quality Control, Reliability Division, Los Angeles section California Western Periodicals Co. 1969 p 1–19

A model is presented for groups whose systems were sequentially deployed into the field and require replacement/repair to sustain a given effectivity level. The term, group effectiveness, is defined in the instantaneous sense, and is the ratio of the number of systems capable of performing as required upon demand to the total number of systems in the group at a given instant of time. Cost versus systems effectiveness is determined once the type of corrective action is decided. Group effectiveness and variable costs were calculated as a function of replacement/repair start time and rate. Three cost categories were identified: penalty or strategic loss costs, logistic costs, and constant costs. The penalty loss costs and logistics costs vary with respect to both the start time and rate. Group effectiveness and total costs associated with a given replacement/repair start time and rate were calculated and presented in a selection matrix which will assist the customer in selecting the optimum replacement/repair policy. Author

Review: This paper presents a model for evaluating the costs of maintenance policies which provide a given group effectiveness, defined as the instantaneous ratio of the number of systems capable of performing as required on demand to the total number of systems in a group at a given instant. Systems in the group are deployed sequentially, and two situations are considered: (1) the order and rate of deployment are known, and (2) systems are deployed randomly throughout the group and individual items are not therefore conveniently traceable. Time to ageout/wearout is assumed to be Normally distributed. The model is straightforward and is described in considerable detail in the paper. Loss functions are derived in an appendix. While the reviewer did not check all of the details of these derivations, a spot check indicates that they are competent. The methods developed in this paper are applicable to the evaluation of cost and systems effectiveness for maintained systems, provided the appropriate input data are available. As the authors point out, they are applicable to situations which involve multiple maintenance cycles which do not overlap.

R70-14847 ASQC 814

THE EFFECT OF VALUE ENGINEERING ON SYSTEM RELIABILITY

Martin T. Pett (Hughes Aircraft Company, Missile Systems Div., Canoga Park, Calif.) *In: Proceedings of the 10th Annual West Coast Reliability Symposium, Beverly Hills, Feb. 21, 1969* Symposium sponsored by the American Society for Quality Control, Reliability Division, Los Angeles section California Western Periodicals Co. p 65–71

Factors related to value engineering are evaluated, and the impact of these factors on equipment reliability is assessed. As almost all major programs contain contractual provisions whereby the supplier can increase his profits by reducing his expenditures, value engineering change proposals are submitted to reduce target cost and increase target profit. Changes which are likely to improve reliability are identified as reductions in parts count or power consumption, improved accessibility and testability, reduction in number and complexity of manufacturing operations, and improved marginal design parameters. Changes which are likely to degrade reliability are cited as relaxation of part testing and quality screening, use of high risk state-of-the-art techniques, and arbitrary relaxation of specification tolerances. Each of these features are discussed in detail. M.G.J.

Review: This is a qualitative paper but the subject is very important, as much to reliability engineers as to value engineers. The thesis is generally agreed upon to be obvious, but as the author suggests, it is the everyday application of the principle which causes trouble. A difficulty often arises when it is not clear how the change will affect reliability—there will often be few available statistics applicable to the problem. One must then perform the usual engineering analyses, e.g., failure modes and effects, to be sure that all of the potential problems which might arise have been covered. As an example, in a parts count reduction, there may be some performance degradation; while lowering the parts count improves the catastrophic failure situation, it generally degrades the performance margin. Changes from a series loss power supply to a duty cycle type can have the benefits mentioned by the author, but also the drastically different wave forms can produce electromagnetic interference (radiated, induced, or conducted). Even though the paper is good, and undoubtedly had a salutary effect on the audience when it was presented, it is doubtful that anyone need seek it out for reference purposes.

R70-14848 ASQC 817

SYSTEM RELIABILITY COST TRADE-OFFS METHODOLOGY

Frank R. Carey (Probabilistic Software Institute, Tujunga, Calif.) *In: Proceedings of the 10th Annual West Coast Reliability Symposium, Beverly Hills, Feb. 21, 1969* Symposium sponsored by the American Society for Quality Control, Reliability Division, Los Angeles section California Western Periodicals Co. p 91–102 7 refs

Existing methods of solving the tradeoffs generally involved in an incentive program are discussed in terms of establishing a target cost and from that a target fee or profit. It is pointed out that

profit is not the only factor involved in the solution of incentive trade-offs; for every unit of improvement on one of the variables, there may be a corresponding degradation of another. An example is given of a contract with incentives only for cost and reliability. Based on the optimistic and pessimistic cost estimates, a formula is given for calculating the target cost, and determining the most probable mean time before failure. Also reviewed are methods of graphing the constraints and possible ways of solving the problem. M.G.J.

Review: This is an interesting and useful topic, and the paper performs a service in bringing it to the attention of the reliability community. The treatment is strictly a straightforward modelling procedure without any regard to its utility, appropriateness, or accuracy. For example, in any derivation of an optimum figure, it is always worthwhile to give some indication of the effect on the optimized variable of minor changes in the independent variables. The reason for this is that rarely is it possible to include in the model all the important considerations. There may be reasons for changing some of the independent variables, even though those reasons were not included in the model. Most often the optimum point is not affected very much by minor perturbations in the independent variables. A model is often approximate, as is the one in this paper where everything has been assumed to be linear and the calculations of the linear parameters are grossly approximate. Thus when reading this paper, it is extremely important to keep in mind that the method given is for optimizing the model, not for the real-life situation. The author does not treat at all the difficulty in incentive contracting where there is more than one allowable variable affecting the profit or the difficulties associated with adjusting the profit-attribute relationship. The customer hopes that when the manufacturer tries to maximize his profit the customer will have his desires fulfilled optimally. But what will happen when the contractor decides to optimize some other figure of merit than immediate profit on this job? The brief discussion of the algorithm for linear programming is sufficient only to refresh someone's memory who is familiar with it already. It will be of negligible value to the beginner. Therefore, this paper is useful for introducing a person to the idea of incentive contracting and contractor trade-offs and for a very qualitative method of picking an approximate optimum point.

R70-14849 ASQC 810; 821

THE STATUS OF RELIABILITY PREDICTION

Clifford M. Ryerson (Hughes Aircraft Company, Culver City, Calif.) *In: Proceedings of the 10th Annual West Coast Reliability Symposium, Beverly Hills, Feb. 21, 1969* Symposium sponsored by the American Society for Quality Control, Reliability Division, Los Angeles section California Western Periodicals Co. p 105–111

The accuracy that can be expected from various types of predictions, and the timing for their optimum use are discussed. Twelve techniques are defined: comparison of similar systems, standardized typical system reliability, comparison of similar circuits, active element group count, generic type part count, detail part estimated stress analysis, detail stress analysis, deficiency technique, simulated operation and part screening, environmental testing, AGREE testing, and field confirmation. The factors which determine the optimum point of application for a given prediction technique are cited as the amount and accuracy of information detail available, and the degree of approximation or accuracy required in the prediction. A guide to the optimum timing for each prediction technique is included. M.G.J.

Review: This paper lists twelve types of reliability prediction, and gives an indication of the timing (i.e., project phase) for their optimum use. Thus the paper has more of a management than a technical orientation. For technical details, the author refers the reader to the forthcoming B revision of MIL HDBK 217 which is being developed by his company. This paper will convey useful information only to those who know virtually nothing about reliability prediction before reading it (i.e., the newcomer to the reliability field). After reading it, they will have a broad outline with none of the technical details filled in.

R70-14850 ASQC 810

IMPACT OF SYSTEM ENGINEERING MANAGEMENT REQUIREMENTS ON THE CAREERS OF RELIABILITY ENGINEERS

Leslie W. Ball (The Boeing Company, Aerospace Group, Seattle, Wash.) *In: Proceedings of the 10th Annual West Coast Reliability Symposium, Beverly Hills, Feb. 21, 1969* Symposium sponsored by the American Society for Quality Control, Reliability Division, Los Angeles section California Western Periodicals Co. p 115–133

As experience has shown that for complex systems a formal process is needed, several Government agencies chose the term, system engineering management process (SEMP), to describe an overall process for controlling the engineering aspects of design, manufacture, and use of engineering products. The major technical steps under SEMP are listed as the identification of the mission, systematic identification of the functions that must be performed, systematic cataloging of contract end items, development of program plans (critical activities), design hardware, make hardware, and use hardware. The business complement to SEMP is described by the term, cost/schedule/technical control system (CSTCS). Product assurance (PA) is considered an important part of the total SEMP. To show the relationship between PA and SEMP, a distinction is drawn between design capability characteristics and product assurance characteristics. M.G.J.

Review: This paper describes the scope and purpose of the "System Engineering Management Process" (SEMP), and shows how traditional reliability and similar assurance disciplines must be fitted into the total management process. The author indicates that there is a movement to integrate the assurance sciences into an overall technology, and to integrate assurance engineers into the mainstream of the process of research, development, manufacture, and use of hardware. The author feels that the SEMP approach will succeed while the "total quality control" approach of some time ago did not, and states his reasons for this opinion. The discussion is clearly presented in reasonable detail, and the main points are summarized in the form of ten figures at the end of the paper. The main message for the reliability engineer is found at the end of the text, where the author clearly sets out those things which the reliability engineer can contribute as a member of the total system engineering management team. Reliability engineers and product assurance managers will find this paper very worthwhile reading.

R70-14852 ASQC 814

RELIABILITY GUARANTEE VERSUS COST OF CAPITAL

T. N. Bowers (Lockheed-California Co., Burbank, Calif.) *In: Proceedings of the 10th Annual West Coast Reliability Symposium, Beverly Hills, Feb. 21, 1969* p 157–163 Symposium sponsored by the American Society for Quality Control, Reliability Division,

Los Angeles section California Western Periodicals Co. p 157–163 1 ref

The contractual requirement for an operational mean time before failure (MTBF) is discussed, and it is pointed out that the mature MTBF may be demonstrated five to seven years after contract award. This delay in demonstrating contract compliance is considered of crucial importance in the reliability development of the equipment because it accentuates the effect of both the time value of money and the general price level rise (inflation) experienced by the economy. A simplified example is given to illustrate how these economic factors can nullify engineering plans.

M.G.J.

Review: The author makes a very good point and one which is rarely recognized in the reliability literature. The essence of the argument is interest rates (time value of money); that is, a commitment to pay someone some money seven years in the future is equivalent from a financial point of view to having to pay him only half that much right now. (The exact ratio depends on the presumed time value of money in the particular case.) The fact that a contractor will take a different approach to the incentives than the customer intended when the contract was written. This is an easily-readable treatment of an important, often overlooked topic. Reliability engineers, especially those in management positions, should be aware of it.

82 MATHEMATICAL THEORY OF RELIABILITY

R70-14807 ASQC 824; 431
RELIABILITY WITH ALLOWABLE DOWNTIME
Marshall Epstein and George Weinstock (Communications and Systems, Inc., Paramus, N.J.) *In: Annals of Assurance Sciences; Proceedings of the Eighth Reliability and Maintainability Conference, Denver, Colo., July 7–9, 1969* Conference sponsored by the American Institute of Aeronautics and Astronautics, the Society of Automotive Engineers, and the American Society of Mechanical Engineers New York Gordon and Breach, Science Publishers, Inc. 1969 p 36–39
(A69-36002)

Approximate solution of the problem involving the reliability of a system with allowable downtimes. The system under consideration is composed of n units of which m units are on fine (operational status). Of the m on-line units, at least k must be operating properly except for acceptable downtime. It is assumed that each unit of the system has independent exponential failure and repair times with n available repairmen. The approach used to solve this problem is one in which the system is considered to be in either one of two states, the good state or the bad state. A new concept (called conditional availability) of being in a particular state at time t conditioned on the fact that the system is not in a bad state at time t is introduced. This concept is incorporated into the solution of the differential equation governing the probability of being in a bad state at time t. An equation which seems intuitively appealing is used to approximate this conditional availability. The solution of the modified differential equation approximates the actual one and is shown to agree with the solution of a single unit system with short allowable downtime, independent of the mean repair or failure times. Author (I.A.A.)

Review: This paper appears to be the approximate solution to the desired problem, as the authors indicate. Several important approximations are made and the paper is tedious to follow especially with the three or four sets of variables that can be involved. The problem itself is an interesting one and should find potential use. Someone who is willing to spend the time might find a more tractable assumption concerning allowable downtime and thus make the solution of the problem easier. In order to use the solution, one will need a knowledge of Markov chains and differential equations.

R70-14809 ASQC 824; 433
MODIFICATION OF GAS TURBINE COMPONENT LIFE PREDICTIONS UTILIZING EXPERIENCE AND THE DISCRETE FORMULATION OF BAYES THEOREM
T. L. Salt and M. H. Monahan (General Electric Co., Aircraft Engine Group, Lynn, Mass.) *In: Annals of Assurance Sciences; Proceedings of the Eighth Reliability and Maintainability Conference, Denver, Colo., July 7–9, 1969* Conference sponsored by the American Institute of Aeronautics and Astronautics, the Society of Automotive Engineers, and the American Society of Mechanical Engineers New York, Gordon and Breach, Science Publishers, Inc. 1969 p 63–68 refs
(A69-36004)

Description of a procedure for modifying design life predictions of gas turbine engine components by using early development test or operational experience. The procedure is applied in the following stages: (1) the interpretation of the designer's life prediction by the Weibull distribution; (2) the determination (from this Weibull distribution) of the probability of crack initiation at a specified inspection time; and (3) the Bayesian modification of this estimated probability of crack initiation by information from parts examined at this inspection time. The approach discussed has been initially successful in providing a statistical assessment and modification of prior analytical design life predictions. I.A.A.

Review: This is an interesting paper on the applications of Bayes' theorem and subjective probability. It is recommended more for those who have had some experience with—and possess a reasonable understanding of—the principles involved in the use of probability as a *degree of belief*. In this situation, the subjective probability is not being applied to the parameters of the Weibull distribution, but to one point through which this Weibull distribution goes, namely, the probability of failure at a given time. The distribution which the authors use to represent the knowledge before the test is very highly peaked at that value predicted by the Weibull distribution, with very small uniform probabilities given elsewhere. One big difficulty with the Bayesian approach is that for any given prior distribution, as data begin to accumulate, the degree of belief does not change very much. When there are a great many data, the degree of belief is determined solely by the data and negligibly by the prior. The region in which both the prior *degree of belief* and the data have reasonably equal influence is very limited. In fact, it is easy enough to draw some asymptotes which show that up to a point, one uses the prior entirely and after that point one uses the experimental data entirely; this curve is not too different from the exact curve. This though is not meant to dis-

parage the use of Bayesian confidence (*degree of belief*) but to point out that more work needs to be done on the philosophy underlying it. This report is worthwhile for several reasons. It shows what people are doing, it encourages other people to investigate this technique more thoroughly, and it strengthens the body of literature on the topic.

R70-14813 ASQC 824

HUMAN AND DESIGN RELIABILITY MEASUREMENT

C. H. Veen (Bendix Corp., Energy Controls Div., South Bend, Ind.) *In: Annals of Assurance Sciences; Proceedings of the Eighth Reliability and Maintainability Conference, Denver, Colo., July 7–9, 1969* Conference sponsored by the American Institute of Aeronautics and Astronautics, the Society of Automotive Engineers, and the American Society of Mechanical Engineers New York Gordon and Breach, Science Publishers, Inc. 1969 p. 135–142

(A69-36013)

Description of an analytical method that requires neither human judgment nor interpretation to determine the source of hardware unreliability, using corrective maintenance records. A number of distinct statistical distributions can be identified by exact measurement of the total maintenance data. Each of these distributions correlates to and effectively separates the basic factors which influence field reliability. These factors include: (1) human factor in production, (2) human factor in maintenance, (3) design factor-random chance, and (4) design factor-limiting life. Use of the technique is particularly recommended where physical access to malfunctioned hardware is not permitted. I.A.A.

Review: The thesis of this paper is that a mortality curve (for equipment), which has been determined from corrective maintenance records, can be analyzed between postulated points of discontinuity in the curve in such a way as to identify the underlying distribution pertaining to each segment of the curve. It is a report of an observed phenomenon, the presence of distinct discontinuities within the distribution of hardware failures which occur during field use. It is postulated that a technique for statistically separating the factors present in the field data can be derived solely from observation of those data. A possible explanation of the phenomenon is based on as yet unproven hypotheses. The paper lacks clarity in a number of ways. Equations are written without definitions of the terms therein. However, from the verbal discussion which precedes each equation, the reader can guess fairly well at the meaning of the terms. The author refers to the "delta method" without ever saying precisely what he means. The statistical approach is based on correlations between observed data and hypothesized statistical distributions. The objective is to determine the specific statistical distribution which provides the best description for the arrangement of the data within each segment of the mortality curve. The limitations of this approach, especially when used with small amounts of data, should be kept in mind by the intended user. The paper will be of interest to reliability analysts who have failure data in which discontinuities similar to those described by the author have been observed.

R70-14818 ASQC 820; 844

RELIABILITY MODELING AND MICROCIRCUIT PREDICTION

C. M. Ryerson (Hughes Aircraft Co., Culver City, Calif.) *In: Annals of Assurance Sciences; Proceedings of the Eighth Reliability and Maintainability Conference, Denver, Colo., July 7–9, 1969* Conference sponsored by the American Institute of Aeronautics and Astronautics, the Society of Automotive Engineers, and the American Society of Mechanical Engineers New York Gordon and Breach, Science Publishers, Inc. 1969 p. 191–198

(A69-36019)

Description of an intermediate-level mathematical model relating failure mechanism, part strength, and the interaction of application stresses to the failure rate of parts in general and microcircuits in particular. Modeling theory and postulates are reviewed and related to the development and use of both partial and complete models. While some aspects of thermal acceleration and stress analysis prediction are dealt with, the choice of an intermediate-level model is based upon empirical tests of its ability to predict failure rates quickly and accurately for any specific application. It is claimed that the application of such a model to microcircuits can result in an accuracy hitherto unachieved. I.A.A.

Review: This paper is apparently an explanation of the concepts and theory involved in the RADC Reliability Notebook, Vol. 2. Volume 2 is a revision of Section 8 of the original Notebook. The first three sections (Introduction, Meaning of Math Models, Deliberate Levels of Complexity and Application) are in general agreement with the thoughts of a great many scientists and engineers. This agreement however is by no means unanimous and there are some paragraphs where exceptions would be strongly taken by some. In Section 4, it is not clear why the Eyring equation was the basis for these other terms any more than the Arrhenius equation would have been. The whole development presumes that the constant hazard rate (failure rate) description of events is adequate—this has been especially disputed in the literature concerning semiconductor devices wherein a decreasing hazard rate is often postulated. Sections 6 and 7 (Complete Detail Models, Modeling Theory Basic Postulates) are not clear, especially in the presentation of the equations. For example, the equation for $\Phi(\alpha T0)$ is not clear, especially (a) the functional notation itself, and (b) the descriptions of α, n, 1. The long equation in Section 6 is even less clear. For example, what are the measures of shock, vibration and electrical load? The appearance of knees in curves strongly depends on what functions of the variables are plotted. In Section 7, the phrase, ". . . dormant operation failure rates for conditions of no stress other than real time . . ." is not clear. The concept of *no stress* is not at all obvious nor is it immediately appearent in what way time is a stress. In assumption #14, it is not clear what ". . . that intrinsic value . . ." is. These comments are not meant to imply that the development is inadequate, just that this report does not explain it clearly in many places. Perhaps if read in conjunction with the RADC Notebook, Vol. 2, many difficulties would clear up.

R70-14831 ASQC 822

THE DETERMINATION OF DISTRIBUTIONS THAT DESCRIBE THE FAILURES OF MECHANICAL COMPONENTS

J. H. Bompas-Smith (Rolls-Royce, Ltd., Aero Engines Div., Derby, England) *In: Annals of Assurance Sciences; Proceedings of the Eighth Reliability and Maintainability Conference, Denver, Colo., July 7–9, 1969* Conference sponsored by the American Institute of Aeronautics and Astronautics, the Society of Automotive Engineers, and the American Society of Mechanical Engineers New York Gordon and Breach, Science Publishers, Inc. 1969 p. 343–356 14 refs

(A69-36031)

Discussion of probability distributions of life or cycles to failure

for a population of parts exposed to constant conditions that cause deterioration and lead to failure. The probability distributions of the level of load over a population of parts are also discussed, and the life or cycles to failure of the population, under field conditions, is developed by combining these two constituent distributions. Examples are given of life or cycle to failure distributions, derived by Monte Carlo methods, from typical constituent distributions. These examples are compared with distributions of life to failure taken from field experience with Rolls-Royce aircraft engine parts. Bimodal distributions that result when some form of weakness is present in a proportion of the population are also developed and compared with the results of fatigue tests and analyzed field data.
Author (I.A.A.)

Review: This paper consists of a theoretical part in which some distributions are derived and a report of experimental findings of field experience. If the theoretical part is viewed more as preliminary speculation than assertion of facts, it is satisfactory and helpful. Many of the statements in it are disputable if made in a categorical form, but are all right if they are interpreted as assumptions. Examples are the following: (1) The central limit theorem results in a *normal* distribution only when the effects are additive. If they are multiplicative for example (additive on a logarithmic scale), the distribution is log *normal* in a central limit theorem. Often when selecting a distribution one is concerned about its behavior out in the tails (say, less than 1% probability) where the failures are expected to occur. Many more variables must be added together (per the central limit theorem) to make the distribution a particular shape in the tails as opposed to the central portion of the distribution. Many of the curves shown are normal, at least outside a few-percent tail region on each end, but it is precisely this tail region that is of concern. The exact shape of the central region is rarely of major importance. (2) It should be remembered that terms like *dynamic strength* and *duty* are vectors (that is, they have several components) and in any complicated situation they are not well defined, that is, they are usually potentially arbitrary functions of measured variables. (3) It is not true that if the dynamic strengths are *normally* distributed then the times to failures are always log-*normal,* even under constant duty. This will be true only under a particular assumption of damage. (4) The equation which says the log{life} is inversely related to the intensity of the environmental energy does not mean much. In the first place, the expression *intensity of environmental energy* is not even defined. The author's formula 3 which is asserted to follow from it contains the *duty* which is also not well defined. The discussion of experimental findings is helpful, but it should be remembered that the log-*normal* distribution has a decreasing hazard rate at long lives; that is, the longer parts last, the less likely they are to fail. This is the exact opposite of wearout wherein the longer a part lasts, the more likely it is to fail.

R70-14836 ASQC 824; 433
PARTIAL PRIOR INFORMATION AND SHORTER CONFIDENCE INTERVALS
John J. Deely and William J. Zimmer (Sandia Corp., Sandia Laboratory, Albuquerque, N. Mex.) *In: Annals of Assurance Sciences; Proceedings of the Eighth Reliability and Maintainability Conference, Denver, Colo., July 7–9, 1969* Conference sponsored by the American Institute of Aeronautics and Astronautics, the Automotive Engineers, and the American Society of Mechanical Engineers New York Gordon and Breach, Science Publishers, Inc. 1969 p 488–496
(A69-36038)

The purpose of this work is to demonstrate one way in which partial prior information can be used efficiently. This is done by means of confidence intervals for the mean-time-to-failure of an exponential reliability model. Partial prior information is taken to mean incomplete specification of a prior distribution, but it is assumed that the prior distribution is sone member of the inverted gamma family. Of the seven different cases of partial prior information treated, two result in full information about the parameters of the prior distribution from which the Bayesian confidence interval can be computed. Four result in the determination of a subfamily of prior distributions from which a "conservative" Bayesian confidence interval can be computed. The case in which only the existence of prior data is assumed results in the computation of an approximate Bayesian confidence interval. In each case, some guidance is provided as to when the confidence intervals proposed can be expected to be shorter than the usual confidence intervals, which ignore the existence of this prior information. Author (I.A.A.)

Review: This paper can appeal to statistically oriented reliability engineers and to applied statisticians (perhaps even theoretical ones). Unfortunately for the ordinary design and reliability engineer, the notation and mathematical statistics are difficult to follow without a moderate amount of effort and a good background in statistics. Even though Bayesian formulas are used, the formulation of the problem is such that probability is not being used in the degree-of-belief sense, but in the conventional relative-frequency sense. This paper is a good contribution for those who want to answer pressing engineering questions with the aid of statistics. (Two minor comments on the editorial preparation are the following. (1) In the introduction, time-to-failure is used whereas time-between-failures is probably meant, since any given computer will only fail once if it is not repaired. (2) There is a misprint in Section 1 between (5) and (6); c and d should be changed to v and w respectively.) All in all, this is a good paper and deserves to be read critically in order to advance the state of the art.

R70-14838 ASQC 824; 412; 433
BAYESIAN CONFIDENCE LIMITS FOR SYSTEM RELIABILITY
M. D. Springer (Arkansas University, Fayetteville, Ark.) and W. E. Thompson (General Research Corp., Santa Barbara, Calif.) *In: Annals of Assurance Sciences; Proceedings of the Eighth Reliability and Maintainability Conference, Denver, Colo., July 7–9, 1969* Conference sponsored by the American Institute of Aeronautics and Astronautics, the Society of Automotive Engineers, and the American Society of Mechanical Engineers New York Gordon and Breach, Science Publishers, Inc. 1969 p 515–523 17 refs
(A69-36041)

Bayesian confidence limits are obtained for systems consisting of (1) exponential subsystems in series; (2) redundant exponential subsystems with high reliability, and (3) subsystems whose life distributions are unspecified. The problem is basically that of deriving the distribution of a product of independent random variables, for which the Mellin integral transform is a natural tool. Application of method to structural reliability, assuming a Weibull model for fracture strength, is briefly discussed.
(I.A.A.) Author

Review: This is a theoretical paper and while it possibly is addressed to the design engineer, the formidability of the statist-

ics/mathematics renders it intelligible only to those with some sophistication therein. Not all the mathematics was checked, but it appears to be competent. Probability appears to be used in its degree-of-belief sense. It is apparently assumed that naturally conjugate priors are being used; there is no discussion of how one picks the particular parameters for those distributions. The paper will be useful to those who are concerned with evaluating the reliability of systems. The techniques developed here will expand the satistician's arsenal of weapons with which to attack a problem of system-reliability estimation. If this estimation is to be contractually used, however, some negotiation mechanism has to be set up for agreeing on the prior distributions, and that probably requires having the negotiators learn enough about the logical implications of using a particular prior to be able to debate the points effectively. While this matter was not the topic of the above paper, it will be of importance in any attempt to apply the theory. It was not feasible to check the programs given at the end, but one of the subroutines which is called FSPIE is not given. The fact that some of the confidence limits are exact will probably be of little consolation to those who disapprove of Bayesian procedures in the first place.

R70-14841 ASQC 824

A GENERALIZED LIMIT THEOREM FOR RELIABILITY

Ralph A. Evans (Research Triangle Institute, Research Triangle Park, N.C.) *IEEE Transactions on Reliability*, vol. R-18 p 45–46 May 1969 1 ref NASA-supported research (A69-37068)

Description of a new and more general limit theorem in place of the exponential limit theorem of Drenick. It is shown that as time goes to zero, the hazard rate can be made to approach an almost arbitrary function. It is pointed out that in the exponential limit theorem (and others) the only practical and necessary effect of having the number of elements "go to infinity" is to force time to go to zero. Therefore the limit theorems are not as useful as was once thought. Author (I.A.A.)

Review: It is often of importance in reliability theory (and practice) to make a statement concerning the probability distribution of the time to the first failure of complex equipment. "Complexity" in this case means that the piece of equipment is made up of many components and fails when any one of the components fails. It is usually also assumed that the component failures occur statistically independently. In this paper, earlier results are shown to be subsumed under a new and more general one, namely this. Suppose that the cumulative hazard function H(t) of the equipment can be decomposed into a sum of two terms, $H_1(t)$ and $H_2(t)$ such that *l*im t yields o $(H_1/H_o) = 0$ then H(t) will approach $H_o(t)$ as N grows very large, (for t fixed) or, equivalently, as t goes to zero (for N fixed). Several examples are given to show the utility of this theorem. (It should be noted that the Evans paper applies to only a portion of the Drenick paper in which the earlier result was presented.)

R70-14846 ASQC 822; 831

THE RELIABILITY OF LONG LIFE REPAIRABLE EQUIPMENT

Herbert G. Jacks (Singer-General Precision, Inc., Librascope Group, Glendale, Calif.) *In: Proceedings of the 10th Annual West Coast Reliability Symposium, Beverly Hills, Feb. 21, 1969* Symposium sponsored by the American Society for Quality Control, Reliability Division, Los Angeles section California Western Periodicals Co. p 49–63 7 refs (A69-31134)

Discussion of reliability and mean time between failure (MTBF) for practical situations in which the equipment contains limited-life components and materials and is operated in a normal-life maintenance environment. Real-life and idealized survival curves are reviewed to get a grasp of the problems involved in making such calculations. Some real-life survival functions and some idealized mathematical models are considered. I.A.A.

Review: This paper is essentially the same as the one covered by R69-14744.

R70-14851 ASQC 824; 825

A METHOD OF PREDICTING AND APPORTIONING SYSTEMS EFFECTIVENESS ESTIMATORS

John M. Feeley (Booz-Allen Applied Research Inc., Los Angeles, Calif.) *In: Proceedings of the 10th Annual West Coast Reliability Symposium, Beverly Hills, Feb. 21, 1969* Symposium sponsored by the American Society for Quality Control, Reliability Division, Los Angeles section California Western Periodicals Co. p 135–155 3 refs

A method for solving the reliability and availability of a hardware item using a Markov procedure is presented. Discussed in detail are the procedures for selecting the state space; determining the corresponding difference equations, creating the set of first order differential equations, determining the transition matrix and solving the resulting set of equations to find the reliability and availability. In addition, a method is presented whereby certain equally likely states can be grouped providing they commute with the same adjacent state. A method of apportioning these values in which the individual sub-item availability and reliability values themselves are increased to meet some preassigned goal is discussed. This method will handle any distribution and does not depend on its corresponding failure or repair rate function. Author

Review: This is a good discussion of a particular model. The technique is reasonably straightforward. Using it will require some knowledge of Markov chains and sophisticated matrix notation. The explanations (on page 138) of equation 4 contain misprints: the second argument of ϕ should be μ rather than t. The author in a private communication has indicated the following additional corrections: . . . the first equation in (5) should read $\phi i,o(\lambda,\mu)$ and not $\phi 1,0(\lambda,\mu)$ as was printed; also, the A matrix on page 139 should be modified so that the diagonal elements have only a single subscript (i.e., $-\phi 0,0(\lambda,\mu)$ should be $-\phi 0(\lambda,\mu)$ etc.). This change will allow Equation (5) to be expressed exactly as printed in matrix terms." Perhaps the most important thing in deciding how applicable this technique will be is whether or not a Markov chain is adequate to model the process. If it is used, all the repair and hazard rate functions use time as measured from the origin only, not any place else. This is satisfactory when one is willing to use constant hazard and repair rates as is usually done and as the author actually does in his examples. But if a set of bearings were considered to have a log*normal* or a wearout distribution such as the *normal* or Weibull, then a knowledge of past events is important; the assumptions made in the text that behavior at any instant is independent of behavior at past instants (when a new failure will occur is independent of when the previous failure occurred) are not applicable. In the private communication mentioned above, the author has made the following statement. "To comment on the fact that the initialization of the process was performed fort t = 0 with the vector [1,0,0, . . .]; the reliability and availability for any value of t

can be examined by using the row vector which results from equations (12) and (13), page 141, providing the states are not summed by the column vectors [11, 12 — 1k]' or [11, 12 – 1k,0,0 –]' respectively, this vector then becomes the new initializing vector and the process continues." In summary, this is a good, if somewhat sophisticated, treatment of the model. Before using it, one must be very careful that the model is appropriate. It will often not be appropriate.

83 DESIGN

R70-14805 ASQC 830; 815
RELIABILITY AND MAINTAINABILITY OF THE FAA'S ARTS-3 TERMINAL AIR TRAFFIC CONTROL SYSTEM
John C. Mercer (Federal Aviation Administration, Systems Research and Development Service, ATC Development Div., Washington, D.C.) *In: Annals of Assurance Sciences; Proceedings of the Eighth Reliability and Maintainability Conference, Denver, Colo., July 7–9, 1969* Conference sponsored by the American Institute of Aeronautics and Astronautics, the Society of Automotive Engineers, and the American Society of Mechanical Engineers New York Gordon and Breach, Science Publishers, Inc. 1969 p 12–21
(A69-36000)

Assessment of the FAA's ARTS-3 terminal air traffic control system proposed by the Federal Aviation Agency in terms of reliability and maintainability. It is pointed out that in the next ten years air traffic will more than double and reliability will be dictated by considerations of safety. Since the ARTS-3 system takes into account the situation of increasing demands with the addition of modules in the course of time and possesses a degree of adaptability according to the needs of the individual terminal, it is capable of ensuring the present level of safety as traffic increases in the future. I.A.A.

Review: About half of this paper is devoted to a description of the system in terms of its subsystem components and the balance describes the reliability goals for subsystems and means of achieving those goals. It is the kind of analysis that appears in a conceptual design of a system. It will be useful to anyone who wants information on that level. Everything in the paper appears reasonable and it is to be hoped that the FAA has more success in its contractors' meeting reliability specifications than the armed services have had at times.

R70-14811 ASQC 831; 838
IMPROVEMENT IN EFFECTIVENESS OF AN EARTH ORBITAL MISSION THROUGH UTILIZATION OF STANDBY SYSTEMS
S. S. Calderon and F. E. Senator (McDonnell Douglas Corp., McDonnell Douglas Astronautics Co., Western Div., Huntington Beach, Calif.) *In: Annals of Assurance Sciences; Proceedings of the Eighth Reliability and Maintainability Conference, Denver, Colo., July 7–9, 1969* Conference sponsored by the American Institute of Aeronautics and Astronautics, the Society of Automotive Engineers, and the American Society of Mechanical Engineers New York Gordon and Breach, Science Publishers, Inc. 1969 p 105–114 9 refs
(A69-36010)

Description of the results of an investigation into the application of standby launch vehicles, spacecraft, and space-station systems to increase the overall mission effectiveness of an earth orbital space program. A systems analytical approach was undertaken to obtain constraints, success probabilities, and an optimum level of spares and logistic demands so that adequate data would be provided to determine compatibility with, or feasibility of, the approach. The results indicate that standby's will generally increase the success probability of a long-term space mission. Their availability would be cost effective whether they would be used or have to go back to storage. In addition, the safety aspects of the program would be greatly enhanced, and planning for follow-on programs could be undertaken with confidence. I.A.A.

Review: This paper is written on a systems level; improvements in reliability are calculated with regard to redundancy (hazard rate is the operating value at all times) and standby (hazard rate is zero when in the standby condition). It discusses the factors that must be considered for reliability improvement and does it well. It will be of primary value only to those engaged in similar occupations and in terms of the results shown in the paper. The mathematical models are not shown (except in one case) but are presumably the very standard ones most often used. It is a good paper for the purpose.

R70-14824 ASQC 832
QUANTIFICATION OF HUMAN PERFORMANCE
Alan D. Swain *In: Annals of Assurance Sciences; Proceedings of the Eighth Reliability and Maintainability Conference, Denver, Colo., July 7–9, 1969* Conference sponsored by the American Institute of Aeronautics and Astronautics, the Society of Automotive Engineers, and the American Society of Mechanical Engineers New York Gordon and Breach, Science Publishers, Inc. 1969 p 251–254 14 refs

A brief history of human reliability work is presented to illustrate the serious problems connected with performing human factors reliability analyses. A central bank of human performance data is identified as the primary requirement. Stress is placed on the need to collect data, try out existing human factors reliability analysis techniques, see what problems there are in using them, check the validity of their outputs, and make appropriate modifications. M.G.J.

Review: Besides serving as an introduction to a conference session on the quantification of human performance, this paper presents a brief history of work on human reliability. As the author is one of the prominent contributors to this work, the history which he presents is based on personal experience with much of it. The presentation takes the form of a literature review, and fourteen references are cited for those who wish to obtain more detail. A significant need which the author emphasizes is that of a central bank of human performance data. It is to be hoped that this need will gradually be met as more system designers become aware of the large role that human performance plays in system effectiveness. It is worth noting that the author feels that the human reliability problem is best attacked by applying human factors technology rather than by assuming that people will not make errors if only they can be persuaded to try harder.

R70-14825 ASQC 832

USE OF A HUMAN RELIABILITY TECHNIQUE TO SELECT DESIRABLE DESIGN CONFIGURATIONS

D. Meister (Bunker-Ramo Corp., Canoga Park, Calif.) *In: Annals of Assurance Sciences; Proceedings of the Eighth Reliability and Maintainability Conference, Denver, Colo., July 7–9, 1969* Conference sponsored by the American Institute of Aeronautics and Astronautics, the Society of Automotive Engineers, and the American Society of Mechanical Engineers New York Gordon and Breach, Science Publishers, Inc. 1969 p 278–282 7 refs (A69-36026)

Evaluation of six subsystem designs on the basis of a human reliability technique as a part of a study of how engineers design. The subsystem designs were compared with equipment reliability evaluations of the same designs. The problems involved in applying a human reliability metric are described. I.A.A.

Review: The author reports his experiences in applying a human reliability technique to predict the effectiveness of subsystem design. While the paper is quite brief, it is sufficient to give design or reliability engineers a good general picture of what was done and of the principal problems which were involved. For those who wish more detail on the human factors aspects, the author cites seven references. Of particular interest for more detail on the "human reliability" method is the author's reference (3), which was covered by R68-13971. In that review, it was mentioned that people working in the human factors area are presented with a dilemma in that the more accurately descriptive a model they have of a system, the less able they are to use the available data, so that the making of an accurate prediction is difficult. This did present a problem in the work reported by the author in the present paper. As he says, "The fact that there is rarely enough detailed information to satisfy a prediction technique which demands detailed information means that there is a fair amount of subjectivity in its application." However, the author concludes that it is feasible to apply the human reliability technique quite early in design, and that despite its inadequacies the technique is useful in a comparative, if not an absolute measurement, sense. Despite many opinions to the contrary, this situation is not dissimilar to that for hardware. It is reasonable to expect that further experience in using human performance predictions in actual system development situations will result in refinements to make them more usable. This paper will be of practical interest to design and reliability engineers who may wish to consider using the techniques.

R70-14833 ASQC 831; 612; 872; 882

ANALYSIS OF SHIPBOARD ELECTRONICS USING SIMULATION TECHNIQUES

Charles C. Eliot and Richard Briggs (Raytheon Co., Missile Systems Div., Bedford, Mass.) *In: Annals of Assurance Sciences; Proceedings of the Eighth Reliability and Maintainability Conference, Denver, Colo., July 7–9, 1969* Conference sponsored by the American Institute of Aeronautics and Astronautics, the Society of Automotive Engineers, and the American Society of Mechanical Engineers New York Gordon and Breach, Science Publishers, Inc. 1969 p 403–416

An example is given to show that the simulation technique can be used for determining the reliability, maintainability, availability, readiness, and safety characteristics of a typical shipboard electronics system. The synthesized mission for this ship is to embark and land troops and supplies to a troubled area. Successful accomplishment of this mission is dependent upon the timeliness, efficiency, and accomplishment of the following tasks: load troops and supplies (T&S) during hostile actions; land the T&S in the hostile area using landing craft and amphibian vehicles; reembark the troops for return to port; provide overall command and control facilities for the operation; maintain control over all landing vehicles; control all aircraft in the area which are supporting the operation; and defend against surface craft and low flying targets. Author

Review: This is a practical paper which shows how some assurance parameters (readiness, reliability, maintainability, availability, and safety) are calculated for a simulated system. In general, it is a good paper and someone with at least some background in computer simulation can improve his knowledge of how he might handle his own problems. There are several flow charts which illustrate the method and some sample printouts which illustrate the results. Several points are not too clear. The following are examples. (1) In the definitions of probability-of-repair and maintainability, administrative time is eliminated from downtime and thus eliminated from readiness. Yet a system down due to administrative delays is just as down as one due to any other reason. (2) The repair time is assumed to be exponential in the introduction and log*normal* under the simulation model. (3) Under readiness, the last sentence in the paragraph about when the probabilities of failure and repair are greatest is not at all clear. This is perhaps because T1 and T0 are not defined well enough. None of these difficulties interferes with the general concepts involved, and they can be ignored by someone who wishes to learn more about his own simulation problems by reading the paper.

R70-14834 ASQC 831

A COMPARISON OF STATIC AND DYNAMIC SYSTEM EFFECTIVENESS ANALYSIS

Gordon L. Seller (Honeywell, Inc., Minneapolis, Minn.) *In: Annals of Assurance Sciences; Proceedings of the Eighth Reliability and Maintainability Conference, Denver, Colo., July 7–9, 1969* Conference sponsored by the American Institute of Aeronautics and Astronautics, the Society of Automotive Engineers, and the American Society of Mechanical Engineers New York Gordon and Breach, Science Publishers, Inc. 1969 p 417–425 5 refs

A system effectiveness analysis is often performed on new system designs to evaluate the system characteristics in accordance with the mission requirements. In addition to the identification of an efficient system design, it is also desirable to perform the system effectiveness analysis in an efficient manner. The comparison of a static and dynamic system effectiveness analysis illustrates how the application of computer techniques can improve the efficiency of performing the system evaluation. The dynamic system effectiveness analysis also provides a greater amount of information on the system degradation than is generally available through the use of a typical manual analysis. The dynamic system effectiveness analysis will therefore simplify the analysis procedure and expand the total amount of information obtained from the mission evaluation. Author

Review: The dynamic analysis referred to in this paper considers effectiveness as a function of time, whereas the static analysis considers effectiveness at a specific point of time. The basic assumptions are standard, involving the exponential reliability function, and the WSEIAC system effectiveness model. The dynamic analysis is accomplished by expanding the basic WSEIAC model through the use of the System Effectiveness State Diagram Interpretive Program (SESIP). The paper is clear and well organized, illustrating the details of the technique through the medium of two

mission examples. It demonstrates the application of computer techniques in a system effectiveness analysis. The SESIP input data format is given in an appendix, but no statement is made as to the availability of the actual program. Perhaps this information is available from the author.

R70-14839 ASQC 831; 612

SIMULATION METHOD APPLIED TO RELIABILITY ANALYSIS OF TURBOJET ENGINE COMPONENTS OPERATING IN AIRLINE SERVICE

R. S. Dorsey and H. A. Truscott (General Electric Co., Aircraft Engine Group, Cincinnati, Ohio) *In: Annals of Assurance Sciences; Proceedings of the Eighth Reliability and Maintainability Conference, Denver, Colo., July 7–9, 1969* Conference sponsored by the American Institute of Aeronautics and Astronautics, the Society of Automotive Engineers, and the American Society of Mechanical Engineers New York Gordon and Breach, Science Publishers, Inc. 1969 p 524–529
(A69-36042)

Brief description of a computer program generated to assess the reliability of a turbojet engine compressor disk. System simulation and Monte Carlo techniques are methods used in the program. The effects and interactions of airline maintenance policy and component and engine design parameters are investigated. The results obtained and a sample problem are discussed. I.A.A.

Review: This is a good paper. It is written so as to be understandable to design and reliability engineers who might use it. Although it deals with simulation, there is no complex computer jargon through which to wade. Reading this paper can give engineers more knowledge about what simulation involves, so that they are more likely to call in a computer expert to discuss simulating their own problems on a computer. For those who are not aware of how simulation is performed on a computer, reading this article would help. It emphasizes that all of the formulas for behavior of all the parts (whether probabilistic or deterministic) must be plugged in. All the computer does is exercise these formulas very rapidly, so that it can be done many times without using up all the money. But the computer does not magically somehow come up with answers that are not directly implied by the formulas which the engineer has previously inserted. This very practical fact is sometimes overlooked by those who have had no contact with using computers to help with complex problems. If you are wondering whether simulation might help in your problem, this is a good paper to read. It has the additional merit of being brief.

R70-14842 ASQC 831; 612; 838; 844

OPTIMIZATION BY INTEGER PROGRAMMING OF CONSTRAINED RELIABILITY PROBLEMS WITH SEVERAL MODES OF FAILURE

Frank A. Tillman (Kansas State Univ., Manhattan, Kansas) *IEEE Transactions on Reliability*, vol. R-18 p 47–53 May 1969 8 refs NASA-supported research
(A69-37069)

Reliability optimization problems with N stages or subsystems in series, utilizing parallel or series redundant units, can be formulated and solved as integer programming problems. The systems considered have subsystems with components which can fail in several modes and are subject to linear and nonlinear constraints. Two situations are considered in which components within the subsystem (1) all fail in the same mode, or (2) all may fail in different modes. Expressions are developed for the probability of failure in each case. Two examples are solved. Author (I.A.A.)

Review: The statement of the problem occupies a large portion of this paper; putting the problem into this formulation is one of the contributions of the paper. People who are involved with systems wherein safety and reliability involve "opposite" kinds of failures should be aware of the contents of this article. Unfortunately, the author does not make explicitly clear in what way redundant elements are considered to be logically in series. The explanation apparently is (but this explanation is not the author's): the situation arises where there is more than one failure mode and the system is made parallel-redundant for the major failure mode. The items then may be in series (and definitely nonredundant) for the minor failure mode. Several resistors in parallel, with opening being the major failure mode and shorting the minor failure mode, illustrate the situation. The reason the failure mode which is cured by redundancy is called *major*, and the other one *minor*, is that this was obviously the designer's feeling. He protected against the one while making the other more severe. The author does have examples which eventually make his formulation of the problem clear. The other main contribution of the paper is to having the formulation of the problem be amenable to solution by integer programming. (One will learn little about integer programming from the text but if he is already somewhat familiar with it, he can then follow the details of the examples.) The following comment may merely reflect the fact that after something has been invented, it appears to be obvious. It seems doubtful that the problem formulation (not counting the method of solution) is new in terms of actual use, although this may be the first publication in the open literature for it. Those concerned with both system safety and reliability have needed equations similar to this.

R70-14844 ASQC 831; 612

A COMPUTER MODEL FOR SYSTEM RELIABILITY PREDICTION

Paul Chelson (Jet Propulsion Laboratory, Pasadena, Calif.) *In: Proceedings of the 10th Annual West Coast Reliability Symposium, Beverly Hills, Feb. 21, 1969* Symposium sponsored by the American Society for Quality Control, Reliability Division, Los Angeles section California Western Periodicals Co. 1969 p 21–35 2 refs

The algorithm and computer program are described for calculating system probability of success for an arbitrary block diagram, given probability of success for each of the blocks in the diagram. The input is simply the block diagram coded in an obvious manner and the probability of success for each of the blocks. The algorithm is based on the probability tree approach to system reliability. Among the advantages cited are the following: (1) The model can handle all forms of active redundancy and potentially can include standby and partial redundancy. (2) The block probabilities may be varied as many times as desired during execution of the program, with negligible increase in computer time. (3) The input/output is extremely flexible, e.g. failure rates and operating hours may be entered instead of probabilities, or the diagram coding may be changed to fit other situations such as fault trees. Author

Review: This is a very qualitative description of the computer program. It is not possible to deduce from it the correctness of the basic algorithm. However, there is no reason to suppose that it is not correct. If it is feasible to generate the required reliability block diagram from the system description, then this computer

program will be of value. For small systems, this is usually not a problem. For large systems, especially where there are many redundant paths, the situation is inordinately complicated. In the early days of modelling these systems, one was told to make a truth table and mark each combination of all of the blocks as success or failure. This had the same difficulty. The question is ordinarily not one of being right or wrong but of finding the easiest way to do a job. If your system can be put in this required format without more effort than required by some other method, by all means go ahead and use this one. There are many things this program does not do, but which could be handled by subroutines which a user could add if he has the resources, for example, calculating the reliability of each block as a function of time.

84 METHODS OF RELIABILITY ANALYSIS

R70-14810 ASQC 844

PHYSICS OF FAILURE IN SPACECRAFT APPLICATION

H. Stuart Dodge (General Electric Co., Missile and Space Div., Philadelphia, Pa.) *In: Annals of Assurance Sciences; Proceedings of the Eighth Reliability and Maintainability Conference, Denver, Colo., July 7–9, 1969* Conference sponsored by the American Institute of Aeronautics and Astronautics, the Society of Automotive Engineers, and the American Society of Mechanical Engineers New York Gordon and Breach, Science Publishers, Inc. 1969 p 100–104

(A69-36009)

Description of the details of space hardware which failed during environmental testing. By simulating the conditions of a space environment, many of these failures can be isolated initially on the black-box level. Examples are given for the failure of magnetic latching relay, a silicon controlled rectifier, a high-dissipation power transistor, and other hardware. Some techniques for pretesting such equipment are outlined. It is noted that, while mechanical signature analysis can detect changes produced by loose debris, a thermal vacuum test is the most powerful tool at the disposal of the missile and space vehicle engineer. I.A.A.

Review: This paper gives a few case histories of failure and the methods of analysis that showed what happened. There is no doubt that the causes of failure were correctly located, but some of the explanations in this paper are incomplete at best. The following are examples. (1) It is stated that in vacuum there is virtually no radiation, only conduction (for heat transfer). This is patently false; the only thing that falls off in vacuum is convection. Radiation may even be slightly increased due to the removal of "gray" material. As those familiar with the Pirani gauge in vacuum work know, heat transfer by convection stays the same as the pressure is gradually reduced from atmospheric. There comes a point when the pressure is low enough that the heat loss by convection begins to decrease (about 1-10 torr). This keeps up until the heat loss is virtually zero (at about 0.0001/0.00001 torr). Pressure reductions below that point will cause negligible change in heat removal by convection compared to that by conduction and radiation. (2) Another example implies that vacuum is a poor electrical insulator. The trouble with that concept is the ambiguity in the word *vacuum*. As pressure is decreased from atmospheric, the breakdown voltage tends to decrease until some rather low pressure is reached (usually in the 0.01-10 torr range). Then the breakdown voltage rapidly increases with a decrease in pressure. The latter increase is sufficiently strong so that some of the best electrical relays are vacuum relays. It is also not clear from this example whether the arcing was a surface arcing or arcing through the gas. If it was through the gas, it is not clear whether vapor contaminants played any part in it. (3) In explaining the utility of soft conformal coatings in hard potted circuits, it should be emphasized that the utility comes largely from the porosity of the coating. Most rubbers by themselves have very small bulk compressibility. Their major utility is in being able to deform readily. The examples do show that attention to detail is important and some of the kinds of detail to which it is necessary to pay attention in designing electrical circuits for a spacecraft environment. In this day and age, most designers engaged in this business should have a rather lengthy checklist (or else have it on a computer somewhere) to enable them to consider these factors.

R70-14814 ASQC 844; 814; 851

MISSION ASSURANCE THROUGH INTEGRATED TESTING

J. W. Carter (Martin Marietta Corp., Denver, Colo.) *In: Annals of Assurance Sciences; Proceedings of the Eighth Reliability and Maintainability Conference, Denver, Colo., July 7–9, 1969* Conference sponsored by the American Institute of Aeronautics and Astronautics, the Society of Automotive Engineers, and the American Society of Mechanical Engineers New York Gordon and Breach, Science Publishers, Inc. 1969 p 145–152 8 refs

(A69-36014)

Description of an approach to the development of an integrated test program based on mission requirements and on failure mode and effects analysis with feedback from the testing to the design and development functions. Case histories are presented on electromechanical components to illustrate the improvement resulting from integrated testing. It is pointed out that the effectiveness of any test program is directly related to how available resources are allocated. Examples which illustrate the use of dynamic programming to optimize resource allocations are given. I.A.A.

Review: Anyone who must make his testing more effective can appreciate the discussion in this paper. It has an excellent emphasis on failure modes, effects, and criticality analyses which are especially important in mechanical systems. One often wonders what an author is going to mean by *integrated testing*. In this case, the author apparently means not so much that the testing has been integrated throughout the life cycle from conception to product shipping; but rather he means that the testing is integrated with the design objectives, so that one can be sure that the tests will uncover potential defects. The discussion on the economics of integrated testing is by an example which shows some of the principles involved. In the example, the element of return on the testing investment is the number of failure modes identified. This was undoubtedly for simplicity. Ordinarily, one might wish to identify the failure modes which are doing the most damage to the system in terms of its reliability or some other figure of merit; or possibly one would wish to identify those failure modes which could be fixed and do the most good for the least expenditure of resources in fixing them. These criteria can get complicated and ordinarily one

uses approximate solutions to the problem because the answers are much more sensitive to the original formulation of the problem than they are to the exactness of the mathematical techniques employed.

R70-14817 ASQC 844; 775

INCIPIENT FAILURE DETECTION - THE DETECTION OF INCIPIENT FAILURE IN CERTAIN HYDRAULIC COMPONENTS

Harvey L. Balderston (Boeing Co., Seattle, Wash.) *In: Annals of Assurance Sciences; Proceedings of the Eighth Reliability and Maintainability Conference, Denver, Colo., July 7–9, 1969* Conference sponsored by the American Institute of Aeronautics and Astronautics, the Society of Automotive Engineers, and the American Society of Mechanical Engineers New York Gordon and Breach, Science Publishers, Inc. 1969 p 181–196 6 refs (A69-36018)

Demonstration that the basic causes of failure in hydraulic systems are associated with structural defects in hydraulic components caused by manufacture, human errors, or the operating environment. Destructive cavitation is studied to find out how and where it occurs and what portions of the mating surfaces in valves are destroyed by its effects. Detection of the degree of increased leakage flow is one excellent indicator of the severity of damage. A second indicator is the existence of cavitation itself. I.A.A.

Review: This paper deals intensively with the behavior of hydraulic valves and orifices; hydraulic systems are an extremely important part of airplanes and space vehicles. It does appear to have been a good set of experiments and has apparently demonstrated that acoustic emission can be used to detect incipient failures. In some circles, the kind of work reported on in the paper would be called *physics of failure* or *reliability physics*. Regardless of its name, the need is to find out *what* is happening, and *why* it is happening, on a very detailed scale. Although not emphasized in the article, presumably one possible beneficial outcome of the research would be to suggest improvements in design to eliminate some of the degradation mechanisms; the main purpose is to find ways to detect incipient failure. The work reported on is very detailed in the field of hydraulics and will be of interest and value only to those engaged in that field. The detailed research will be of negligible value to design and reliability engineers, but the principles involved are important.

R70-14819 ASQC 845

A SYSTEM FOR EFFECTIVE TRANSFERRAL OF MICROELECTRONIC RELIABILITY EXPERIENCE

H. A. Lauffenburger (IIT Research Institute, Reliability Analysis Center, Chicago, Ill.) and J. L. Fuchs (Griffiss Air Force Base, Rome Air Development Center, Chicago, Ill.) *In: Annals of Assurance Sciences; Proceedings of the Eighth Reliability and Maintainability Conference, Denver, Colo., July 7–9, 1969* Conference sponsored by the American Institute of Aeronautics and Astronautics, the Society of Automotive Engineers, and the American Society of Mechanical Engineers New York Gordon and Breach, Science Publishers, Inc. 1969 p 218–227 2 refs

A system for effectively linking various activities for efficient interchange of relevant microelectronic device knowledge is described. This system, designated the Reliability Analysis Center, assimilates available data and experience information from, and disseminates processed intelligence to all segments of the electronics and scientific community actively concerned with military microelectronics circuits. Services provided by the Reliability Analysis Center and some of the system elements which have been designed to insure integrity and validity of information disseminated are also reviewed. Its main purpose is to convey failure rate and failure mode data obtained from reduction and analysis of selected portions of the current data base. Author

Review: This is a good paper. There is a brief description of the reliability analysis center and the way it operates. The summary of reliability experience on microcircuit devices is good; it is quite up to date. In analyzing the causes of failures, one has to be careful about bewailing the fact that devices fail too much from any particular cause since the sum of all causes must be 100%. If they do not die from one thing, they will die from another—what would you like them to die from? The authors' attitude in this respect is good; other articles have had a misplaced emphasis. All in all, both reliability and design engineers can profit from having this paper available to them. It seems that it would also profit them to use this service to the maximum extent that is economically feasible. In a private communication the first author has supplied the information that the service is now free, but that modest user fees are envisioned. Qualified personnel from DOD, as well as its prime contractors and subcontractors, may deal directly with the Center by contacting:

Mr. Harold A. Lauffenburger
IIT Research Institute
10 West 35th Street
Chicago, Illinois 60616
Telephone: 312/225-9630, ext. 4539
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All others should direct their requests to:

Rome Air Development Center (EMERR, J.L. Fuchs)
Griffiss Air Force Base
New York 13440
Telephone: 315/330-4726; Autovon 947-4726
TWX: 315-33-7760 Attn: EMERR/RAC
Or via Western Union.

R70-14823 ASQC 844

FIELD FAILURE RATES FOR SELECTED KSC GROUND SUPPORT EQUIPMENT

Eloise E. Bean and Charles E. Bloomquist (Planning Research Corp., Los Angeles, Calif.) *In: Annals of Assurance Sciences; Proceedings of the Eighth Reliability and Maintainability Conference, Denver, Colo., July 7–9, 1969* Conference sponsored by the American Institute of Aeronautics and Astronautics, the Society of Automotive Engineers, and the American Society of Mechanical Engineers New York Gordon and Breach, Science Publishers, Inc. 1969 p 244–250 4 refs (A69-36023)

Description of some of the interim results (devoted to mechanical and electromechanical components) of a study conducted for the long-range objectives of deriving failure rates and other reliability data for launch-support equipment. Application of the methodology developed for the Kennedy Space Center (KSC) data to four areas of KSC equipment resulted in a number of field-failure-rate (FFR) estimates and associated confidence factors. In addition to the estimates of the mean FFR for the various populations considered and the confidence intervals for the mean FFR, the MTTF and the minimum and maximum observed times to

failure are presented. Conclusions reached to date are that it is possible to make a meaningful reliability assessment of components from KSC field data and that analysis of field data is the only feasible method for performing a meaningful and useful reliability assessment for specific components. I.A.A.

Review: This is a good paper for several reasons. Obviously, much of its merit is not readily checkable in terms of whether or not as much was done with the data as could be. But in general, it is very likely that this work was about as good as could be done with the resources at hand. This kind of problem exists in many places and is almost impossible to treat. Theoreticians are especially encouraged to read the paper, not because they will learn new techniques, but because they can learn that many people do not have data that fit nicely into previously developed theories. It appears that the quality of the data were such as not to support any very complicated statistical models. As mentioned above, this is often the case in very practical work. The papers on it rarely get published because of the messiness of the situation and newcomers to the field are often bewildered by their first confrontation with this kind of data. After reading this paper, the previous one in these Conference Annals becomes somewhat clearer, if in fact this is the kind of work they were trying to explain.

R70-14829 ASQC 844

FAILURE ANALYSIS-A KEY ELEMENT IN COMMERCIAL PRODUCT RELIABILITY

S. J. Keene, Jr. (International Business Machines Corp., Systems Development Div., Boulder, Colo.) *In: Annals of Assurance Sciences; Proceedings of the Eighth Reliability and Maintainability Conference, Denver, Colo., July 7–9, 1969* Conference sponsored by the American Institute of Aeronautics and Astronautics, the Society of Automotive Engineers, and the American Society of Mechanical Engineers New York Gordon and Breach, Science Publishers, Inc. 1969 p 304–308 1 ref

Guidelines for isolating problems and identifying the cause of failure and examining closely the failed mechanism are presented. Techniques are discussed for finding, analyzing, and solving problems resulting from misapplication of parts, improper test procedures, or deficiencies in component quality. Author

Review: The author rightly points out that (a) to do any good, the analysis of failure must be fed back so as to result in a product improvement and (b) searching for patterns of failure which may be hidden in failure reports is often worthwhile. But this paper is more of a series of case histories than a discussion of the philosophy and procedures of failure analysis. The discussion seems to be implicitly limited to computer elements, but obviously the principles apply not only to all commercial products but to aerospace and industrial products as well. For those who are well acquainted with the benefits in proper use of failure analysis, there is no need to read the paper. Those who are new to the field of reliability can improve their understanding by reading it. In a private communication the author has pointed out that many labs for failure analysis analyze only the odd failure brought to them. They can be much more helpful if they collect large samples, analyze them, and then close the action loop to correct the defects. He intended that to be the message of the paper (and a good message it is).

R70-14830 ASQC 844; 612

COMPUTERIZATION OF SYSTEM/PRODUCT FAULT TREES

Kazuo Kanda (Boeing Co., Seattle, Wash.) *In: Annals of Assurance Sciences; Proceedings of the Eighth Reliability and Maintainability Conference, Denver, Colo., July 7–9, 1969* Conference sponsored by the American Institute of Aeronautics and Astronautics, the Society of Automotive Engineers, and the American Society of Mechanical Engineers New York Gordon and Breach, Science Publishers, Inc. 1969 p 325–333 6 refs (A69-36029)

Description of two basic activities associated with the system-safety fault tree. The first activity is the diagramming or drawing of the fault trees and associated configuration trees that relate to the engineering drawings defining the system. The second is the calculation activity required for the numerical assessment and quantitative analysis of the system. I.A.A.

Review: The title of this paper may be somewhat misleading to the neophyte user of fault trees and computers. The first required input document is a hand-drawn sketch of the entire fault tree; then someone must encode that in a form acceptable to the computer. The computer then does two things: (1) it draws the finished copy of the fault tree from the coded input copy and (2) if the appropriate hazard rates are introduced for the components, it makes the calculations for the probability of failure of the system. These two things are not trivial, but the neophyte should be aware that the computer does not generate the fault tree from anything but the input codes corresponding to a rough draft of the fault tree. The descriptions in the paper are adequate for someone who is familiar with the use of computers, but there is obviously not enough description to enable one to reproduce such a program. Presumably, more information can be obtained from the author. Although it does not relate directly to the purpose of the paper, remember that fault trees are useful in reliability as well as safety analyses and that a failure modes and effects analysis is also fruitful for safety in addition to reliability. One of the difficulties with a fault tree analysis is that traditionally parts have had to be classified as either good (unfailed) or bad (failed); there was no provision for the gradual deterioration or poor fits that occur in all kinds of electronic and mechanical equipment. In a private communication the author has stated that they are working with deterioration. But it is not clear in what way it is different from the usual statistical analysis of deterioration done by using performance equations.

85 DEMONSTRATION/MEASUREMENT

R70-14806 ASQC 850; 814; 844

PROBABILITY SUCCESS OF 0.9000–IT'S A MATTER OF VALUE–AN ESSAY

Irwin Nathan (Xerox Corporation, Webster, N.Y.) *In: Annals of Assurance Sciences: Proceedings of the Eighth Reliability and Maintainability Conference, Denver, Colo., July 7–9, 1969* Conference sponsored by the American Institute of Aeronautics and Astronautics, the Society of Automotive Engineers, and the American Society of Mechanical Engineers New York Gordon and Breach, Science Publishers, Inc. 1969 p 33–35 refs

The use of abstract numbers and k factors by reliability engineers is discussed in terms of the broadening developments which integrate reliability, maintainability, and performance into the mission-oriented, economically constrained real world. It is

pointed out that the sensitivity of the now integrated and constrained number, which includes reliability as only one factor out of several important factors, results in a dilution of the impact of the 1000 to 1 failure ratio. It is also shown that, under appropriate circumstances, a large differential in expected reliability becomes nearly insignificant. Author

Review: This essay is an introduction to a session. Even though the emotional impact comes through much more clearly than the specific details, the author's points are well taken. (Being limited to less than two pages resulted in the author's having to be too brief for good clarity.) All too often, a single figure of merit is chosen for the system, such as 0.99 system effectiveness, and then everyone calculates madly to arrive at a system with this figure of merit. Unfortunately, the person who wanted the system did not pack all of his desires, hopes, and expectations into this single figure of merit; so he may well not get what he wanted. The author's discussion will not always be easy to follow, especially for those not acquainted with the jargon he is using, but the feeling behind it comes through loud and clear. In the design of most systems, there comes a point where the factors which have not been quantified are more important in making decisions than those which have been quantified. In our eagerness for arithmetic precision and mathematical tractability, the author does not want us to lose sight of what the buyer of the system is really after.

R70-14808 ASQC 851; 831

THE SYSTEM APPROACH TO RELIABILITY DEMONSTRATION

J. J. Bussolini and S. A. Weisberg (Grumman Aircraft Engineering Corp., Bethpage, N.Y.) *In: Annals of Assurance Sciences; Proceedings of the Eighth Reliability and Maintainability Conference, Denver, Colo., July 7–9, 1969* Conference sponsored by the American Institute of Aeronautics and Astronautics, the Society of Automotive Engineers, and the American Society of Mechanical Engineers New York Gordon and Breach, Science Publishers, Inc. 1969 p 40–48 refs
(A69-36003)

Description of the factors involved and the problems encountered in a reliability demonstration program. An approach is given for evaluating these factors in a systematic manner within program constraints. The impact of the system design and test requirements on lower levels of testing is discussed, and an orderly transition from system to equipment requirements is given. The relationships between the risks of the procuring agency, system contractor, and equipment producers are described and placed in a meaningful perspective. The intent is to relate the many parameters needed to define the demonstration tests. Parameters such as statistical risk, requirements, criteria for testing, form of test, test cost, and incentives are discussed in nonmathematical terminology. An approach for defining the elements of an effective test philosophy in a practical manner is offered. Author I.A.A.

Review: This is a good paper except for the detailed statistical explanations. The engineering and managerial considerations for planning are very well pointed out and the implications of conducting a demonstration test on reliability are well explained. Obviously, one cannot use this kind of article as a cookbook procedure to follow. But it can alert the non-sophisticated reader to the points on which he must put time, effort, and thought. As is usual in such discussions, classical statistical confidence is to be used in analyzing the tests (as opposed to an approach using degree of belief). Aroian has done a great deal of work with regard to exact α and β fractions on truncated sequential tests. Since the usual formulas are approximate, one of his approaches has been to find out where the test could be truncated and have the nominal fractions be the exact ones. The approach of using total test time and total number of failures (upon crossing a boundary) in the usual chi-square formula for single sample tests is not correct. It will not give the proper confidence limits for the exponential parameter. The exact distribution is a rather complicated one and is not available in the ordinary literature. This mistake is a common one, but a mistake nevertheless.

R70-14826 ASQC 851; 844

TEST AND EVALUATION TECHNIQUES ASSIST RELIABILITY ASSURANCE IN CONSUMER PRODUCTS

Perry P. Bohlool (Whirlpool Corp., St. Joseph, Mich.) *In: Annals of Assurance Sciences; Proceedings of the Eighth Reliability and Maintainability Conference, Denver, Colo., July 7–9, 1969* Conference sponsored by the American Institute of Aeronautics and Astronautics, the Society of Automotive Engineers, and the American Society of Mechanical Engineers New York Gordon and Breach, Science Publishers, Inc. 1969 p 294–297

Basic requirements in the field of testing and verification are presented. These requirements appear in the form of outlined objectives followed by test planning and mode of operation. This has been illustrated by two flow charts of events and activities. Basic emphasis in consumer product testing has been placed on establishment and control of disciplines throughout the test. Example of a test log sheet is followed by a brief outline of preventive values of testing in consumer products. Author

Review: As the author mentions in the early part of the paper, the techniques and discipline of reliability are the same whether applied to aerospace systems or consumer products. The difference is largely a matter of degree. This paper will be of most assistance to those who are relatively new to the reliability field such as designers, managers, and those engineers who have recently been assigned to a reliability effort. As befits such a paper, the language is general enough to be easily understood. There are no complicated mathematics and the paper deals with the general principles involved rather than the specific details. The limitation in the title should be noted, that is, the paper does not deal with other reliability techniques such as design reviews and reliability prediction. This paper can be recommended as good reading for the above group.

R70-14827 ASQC 851

PREDICTING PRODUCT RELIABILITY FROM ACCELERATED TEST RESULTS

C. G. Plithides (General Electric Co., Home Laundry Products Div., Louisville, Ky.) *In: Annals of Assurance Sciences; Proceedings of the Eighth Reliability and Maintainability Conference, Denver, Colo., July 7–9, 1969* Conference sponsored by the American Institute of Aeronautics and Astronautics, the Society of Automotive Engineers, and the American Society of Mechanical Engineers New York Gordon and Breach, Science Publishers, Inc. 1969 p 298–303 5 refs

Details are given on a life test procedure established to obtain an index of the design capabilities of washers and dryers and to simulate the life of these appliances in the field. The test appliances

run continuously to provide acceleration, while preserving, as much as possible, the same environment and usage by the customer. The appliances are selected at random from the assembly line weekly, checked for initial defects, then connected with cycle counters. By using a conversion factor the cycles are changed to years of life and the analysis of the data is performed by grouping the failures in consecutive years. Component failures are repaired during the testing period. As the testing continues, the field warranty information which is the most conclusive measure of customer experience, reflecting both the influence of engineering design and manufacturing variations, are adjusted accordingly. The analysis of reliability measurement for the total machines is based on use of the Weibull distribution. The results are used as a guide for design changes and for estimating the service call rate per appliance in the field. Author

Review: The tests in this report are described as accelerated tests, and it is always instructive to see how someone is accelerating a test. In this case, the ordinary duty cycle is very small and the life (in terms of cycles) is implicitly presumed to be independent of how often the machine is cycled. Therefore, one can accelerate the test merely by eliminating some of the dead time. There is, then, no attempt to increase the environmental severity, such as high temperature. The paper gives a not-too-clear description of what is done. (For example, it is not clear in Tables 4 and 5 what the vertical variable is—in a private communication the author said that they are product service characteristics, and not identified for obvious reasons. The explanation of some of the terminology is not sufficient for someone running across it for the first time; in a private communication the author re-emphasized that the Adders are rates of incidence of failures which are measured in the field, but which are not tested for in the life test.) The method of data analysis appears reasonable; unfortunately, in #4 of the properties of the Weibull distribution, a particular quantity is labelled as a failure rate whereas it obviously is not a failure rate and is merely an abbreviation (confirmed by the author in a private communication). Nonetheless, a reader can get a fairly good idea of the kinds of tests being run, how they are supplemented, and the reasons for supplementing them. One of the important transfers of technology from the aerospace field to the consumer industry is the reliability discipline, and this paper shows how it is being applied for a consumer product. It is important to remember that the manufacturer is not striving for the highest reliability possible within the state of the art but instead he performs a trade-off on price.

R70-14837 ASQC 851; 433

A SEQUENTIAL-BAYES PROCEDURE FOR RELIABILITY DEMONSTRATION

Ray E. Schafer and Nozer D. Singpurwalla (Hughes Aircraft Co., Systems Effectiveness Dept., Fullerton, Calif.) *In: Annals of Assurance Sciences; Proceedings of the Eighth Reliability and Maintainability Conference, Denver, Colo., July 7–9, 1969* Conference sponsored by the American Institute of Aeronautics and Astronautics, the Society of Automotive Engineers, and the American Society of Mechanical Engineers New York Gordon and Breach, Science Publishers, Inc. 1969 p 507–514 6 refs (A69-36040)

Application of the sequential Bayes procedure for demonstrating that the mean time to failure exceeds some minimum acceptable value with a given confidence coefficient. Bounds on the quantiles of the distribution of the number of steps to termination are also developed, together with an approximation to the probability of acceptance. The exponential failure law is considered with an inverted gamma prior and a two-point prior distribution, respectively, on the scale parameter. I.A.A.

Review: This paper presents an interesting procedure for reliability demonstration. Not all the mathematics was checked, but it appears to be quite competent. It is not clear in what sense probability is being used (relative-frequency vs. degree-of-belief), but it appears to be degree-of-belief. In a private communication the first author has stated that $g(\Theta)$ (the prior distribution) was meant to be interpreted in the frequency theory of probability. That is, each equipment has an MTBF (Θ) which is regarded as a random draw from $g(\Theta)$. Thus, the posterior probability can be interpreted in the frequency sense. The paper deals largely with the explanation of the mathematical model. It does not deal with some of the problems one would have in attempting to apply it in a contractual situation. The main difficulty which arises in a contractual negotiation is having both parties agree on the prior distribution which is to be used as the starting point. It is not necessarily an insurmountable difficulty; it is just one that the two parties are not used to having. The authors point out that this demonstration test does answer the question the engineer wants to have answered, namely probabilities about the true value, whereas in the classical procedure he is prohibited from asking that question and has more or less learned to live with the answer to a question he does not care about (the probability of being right or wrong but no knowledge about how right or how wrong). With more and more procedures such as this becoming available for using prior information (and the use of prior information is essential to demonstrating high reliability), someone needs to devote time and effort to presenting papers on how the two parties to a contract can agree on a reasonable prior distribution and of course they have to do this before any reliability demonstration tests are run. In the private communication mentioned above, the first author has indicated that a contract is being funded to investigate how agreement on the prior distribution is to be achieved.

R70-14840 ASQC 851; 815; 844

AN INTRODUCTION TO MIL-STD-883 TEST METHODS AND PROCEDURES FOR MICROELECTRONICS

E. P. O'Connell (USAF, Rome Air Development Center, Griffiss AFB, N.Y.) *In: Annals of Assurance Sciences; Proceedings of the Eighth Reliability and Maintainability Conference, Denver, Colo., July 7–9, 1969* Conference sponsored by the American Institute of Aeronautics and Astronautics, the Society of Automotive Engineers, and the American Society of Mechanical Engineers New York Gordon and Breach, Science Publishers, Inc. 1969 p 530–542 9 refs (A69-36043)

Discussion of the value and cost of visual inspection, thermal and mechanical shock, burn-in, and hermeticity testing of microelectronic equipment. Test methods and procedures of the MIL-STD-883 program are reviewed, and it is shown that this program provides a new and practical approach for improving reliability performance of equipment employing microelectronic devices, without increasing the cost. A summary of experiences with these procedures in the procurement of several hundred thousand devices for USAF systems is given. I.A.A.

Review: This paper is a valuable discussion of MIL-STD-883, "Test Methods and Procedures for Microelectronics," 1 May 1968, and MIL-STD-883, Notice 1 (USAF), 20 May 1968. The author

reviews the intended purpose of these documents and outlines how they should be used, both by the vendor and the government procurement agency. He discusses the justification for a few of the provisions of the standard by reviewing the experimental data leading to a specific recommendation or test method, and assesses the success of the standard over its first year of use. Clearly, the author feels that MIL-STD-883 represents a good, workable solution to the extremely complex problems of microelectronics systems reliability. He convinces the reader that the provisions of this document are well thought-out and have been tailored to the requirements of the real world in the sense that the procedures are both effective and reasonable in cost. The procedures required to achieve a given class of reliability can be implemented by the state-of-the-art manufacturer today without adding prohibitive costs to the end product. A very significant background note to the preparation of this standard is that the manufacturers themselves played a major role in its preparation. The attitude seems to have been one of letting the manufacturers reach agreement as to what constitutes reasonable, effective testing. Once having reached such agreement, however, Government Procurement Agencies can then reasonably insist upon manufacturers performing as previously agreed. Some technical points which are worthy of particular note are the following. (1) The maximum safe temperature for gold/aluminum metallization systems is listed as 150 C in substantial agreement with the conclusions of other publications on this problem. (2) A 30,000 G constant acceleration is regarded as a practical although not adequate screen. It does reveal unsatisfactory chip bonds and inadequate lead dress, but only the weakest wire bonds. (3) Gross leak test procedures utilizing fluoro-carbon liquids are shown to be less destructive and degrading than previous gross leak tests utilizing hygroscopic liquids. (4) The cost factors involved in implementing the standard are broken down into an itemized list. The reliability philosophy described in this paper seems to differ with that contained in the NASA line-certification program (see R69-14579). In the NASA program the manufacturing line itself is scrutinized by the customer. In the MIL-STD-883 procedure, only the finished product (the product prior to lid sealing) is examined, tested, and screened. No checks on the manufacturing line itself are made—unlike the NASA line certification program. In view of the joint sponsorship of this document by both DOD and NASA, the question arises whether these two approaches to electronic device reliability are competitive or complementary. If 883 can do the job, then further manufacturing control would be superfluous and undesirable. The reader of this paper should have a copy of MIL-STD-883 as well as Notice 1 (USAF). Table 1 of the paper lists the tables of contents of both these documents; test methods T5001 through T5006 do not appear in the basic standard but presumably are part of Notice 1. Both these documents are available from the Naval Supply Depot, 5801 Tabor Avenue, Philadelphia, Pa. 19120. Some of the other cited references may not be so readily available; for example, Reference 3, RADC Reliability Branch Policy Statement, "The Recommended Use of MIL-STD-883 Procedures," April 1969, and some of the RADC contract reports. While this paper does not constitute an official publication, it can probably be taken as representing the RADC evaluation of MIL-STD-883 and revealing the recommendations of that organization in regard to AF procurement of electronic systems, both present and future.

87 MAINTAINABILITY

R70-14835 ASQC 872; 882

MAINTAINABILITY—THE MEASURE OF AVAILABILITY

Theodore O. Wright (Boeing Co., Seattle, Wash.) *In: Annals of Assurance Sciences; Proceedings of the Eighth Reliability and Maintainability Conference, Denver, Colo., July 7–9, 1969* Conference sponsored by the American Institute of Aeronautics and Astronautics, the Society of Automotive Engineers, and the American Society of Mechanical Engineers New York Gordon and Breach, Science Publishers, Inc. 1969 p 466–469 2 refs (A69-36036)

Description of a method of defining availability in terms of maintenance demand rate and mean downtime. This involves combining distribution functions for secondary failures, wearout failures, handling damage, human error, performance deterioration, nonoperational defect, environmental effects, test equipment errors, and procedural errors with the primary failure rate calculations so that a mean time between maintenance actions can be determined. The use of this procedure makes it possible to realistically predict and demonstrate equipment or system availability. This will serve as a major step in answering the challenge of predicting the cost of supporting delivered products. Author (I.A.A.)

Review: This paper is concerned with a method for estimating availability in terms of maintenance demand rate and mean downtime. The following ten contributors to the demand for maintenance are identified: equipment reliability, personnel, environmental effects, procedures, secondary failures, wearout failures, performance deterioration, non-operational defects, handling damage, and test equipment errors. There is some discussion concerning the appropriate distribution which is followed by each of the factors. For example, the Weibull distribution is considered appropriate for representing equipment failure patterns, the Poisson distribution for handling damage and human errors, and gamma distributions for procedural errors and environmental effects. These are just mentioned and no real justification for the choice of distribution is given. However, these choices do not seem to be important anyway, since the author concludes that the characteristic distribution of the sum of the factors will be Normal since the individual distribution functions can be treated as independent random variables and the Central Limit Theorem can be applied to them. While the paper contains some good ideas for those who are interested in methods of predicting and assessing the availability of equipments and systems, it should not be considered as more than suggestive of a possible approach which needs further development and justification before being adopted for general use. In a private communication, the author has indicated that his major point is that in assessing or predicting availability one must combine the nonlinear effects of at least the ten demands for maintenance in such a way that each contributor is considered while the sum is evaluated in a meaningful fashion. He feels that assigning a linear factor to one or more nonlinear variables (the "K-factor" approach) leads to error in the estimate. This idea has merit, and while the author's conclusions are not fully substantiated in this short paper, they could indeed point the way to more valid estimating and predicting capabilities in this area.

R70-14845 ASQC 872; 612

PREDICTING MAINTENANCE TIME DISTRIBUTION OF A COMPLEX SYSTEM—A MONTE CARLO SOLUTION

W. R. Downs (McDonnell Douglas Astronautics Co., Huntingdon Beach, Calif.) *In: Proceedings of the 10th Annual West Coast Reliability Symposium, Beverly Hills, Feb. 21, 1969* Symposium sponsored by the American Society for Quality Control, Reliability

Division, Los Angeles section California Western Periodicals Co. p 37–47 3 refs

Details are given on a simulation program developed to support maintainability analyses and design evaluation of space system designs. The logistics support type of interface considerations (supply, support maintenance, etc.) are input to the program as supply times for spares, which may be varied to evaluate effects of stock location or repair/replace policies. The program also provides a list of spares used, showing how often they are used; this list is part of the data used in selecting optimum spares and providing the maximum probability of repair within cost/schedule constraints. Routinely available maintainability and reliability parametric data are used, and the probability density distribution of total maintenance time is synthesized by analyzing a complex sequence of equipment operations subject to failures which may be repaired. Author

Review: This paper gives reasons why it is worthwhile predicting maintenance time, and describes a computer program for making the calculations. It is somewhat difficult to follow. One is not always sure whether the program itself is being described, or what people actually do, or what people ought to be doing. The fact that the computer solves the equations by a Monte Carlo procedure is interesting but probably not important to the user. Of most importance is the series of assumptions upon which the program is based, and these are listed near the end of the paper. The assumptions are as reasonable as any, and since the results are probably rarely sensitive to the very tails of the distribution, the exact assumptions are not critical. The program's being expandable as system design progresses is valuable. There is an error in Eq. 3—only the first term on the right should contain R, the remainder should not; it would have been helpful to indicate an ellipsis at the end of the equation for algebraic completeness. Presumably, those who wish to have copies and descriptions of the program can write to the author for them.

88 AVAILABILITY

R70-14853 ASQC 882; 814

COST EFFECTIVE SPARES PROVISIONING MODELS FOR AIRLINE OPERATIONS

Richard F. Johnson (Lear Siegler, Inc., Astronics Div., Santa Monica, Calif.) *In: Proceedings of the 10th Annual West Coast Reliability Symposium, Beverly Hills, Feb. 21, 1969* Symposium sponsored by the American Society for Quality Control, Reliability Division, Los Angeles section California Western Periodicals Co. p 165–214

Two analytical models are derived for optimizing spare loading for a system by maximization of the ratio of availability to cost of ownership for five years. Once obtained, these optimum points can readily be compared between systems. The choice of model is dictated by the degree of accessibility between repaired units emanating from different aircraft. A computer program is included for applying the analytical model to complex systems which would cause time consuming calculations of the model if performed by hand. Model methodology was developed which can be used for systems with figures of merit other than availability. The results of the sample calculations demonstrate the ease in which unavailability due to waiting for spares is reduced to almost zero by addition of spares; however, the sample calculations underscore the possible effect of down time due to removal and replacement of failed line replaceable units, detection, and repair. The effect is a limitation of the availability to that which is built in. Author

Review: This is a rather long paper, about fifty pages, and contains a great deal of the justification for the model and the mathematical derivations involved in it. The assumptions are well stated. The author adopts the desirable policy of repeating the assumptions on occasion and regrouping them for emphasis and clarity. Little of the mathematics itself was checked; it appears to be competent. The rationale for the models is given and is relatively easy to understand. If one were actually to try to apply the model to his own system, however, it would require extensive study of the paper and the learning of the author's nomenclature. The models have been kept reasonably tractable by making appropriate simplifying assumptions. (It is certainly possible to create models which take many more factors into account.) The procedure for arriving at the optimum point is good except that one may wish to continue the process, once the total cost starts to rise, in order to get an idea of the shape of the minimum. One could easily wish to operate at one side or another of a very shallow minimum point because of other factors not explicitly included in the model, especially if this can be accomplished at a very nominal cost increase. There is sometimes a tendency to analyze a model very exactly and forget that it only approximates the real situation.

SUBJECT INDEX

Typical Subject Index Listing

PROBABILITY
Procedures for applying sequential probability ratio tests in analyzing checkout and support equipment
TR-3 c84 R70-12733

SUBJECT TERM | REPORT NUMBER | NOTATION OF CONTENT | CATEGORY NUMBER | *RATR* ACCESSION NUMBER

The Notation of Content, rather than the title, is used to provide a more exact description of the subject matter. The category number and *RATR* accession number are used to locate the abstract-review appearing in the abstract section of *RATR*.

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B

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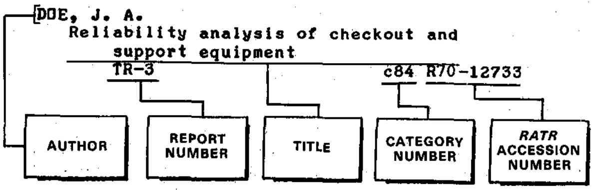
PERSONAL AUTHOR INDEX

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS VOLUME 10 NUMBER 1

Typical Personal Author Index Listing



The category number and the *RATR* accession number are used to locate the abstract-review appearing in the abstract section of *RATR*.

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REPORT AND CODE INDEX

List of Report Numbers

This may be used to identify the *RATR* accession number of reports covered in this journal. To the right of each report number is the *RATR* accession number preceded by the category number for locating the abstract-review in the abstract section of *RATR*. For purposes of this index, AD, N, and A numbers (accession numbers from *TAB*, *STAR*, and *IAA*, respectively) and ASQC code numbers are treated as "report" numbers. Thus, the section of this index listing ASQC codes may be used to identify the *RATR* accession number of the coded abstract-reviews appearing in *RATR*.

ACCESSION NUMBER INDEX

List of *RATR* Accession Numbers

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NASA-Langley, 1970

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The second section of *RATR* contains four indexes: The Subject Index is to assist in scanning or searching the literature on specific topics. The Personal Author Index identifies the publications of specific authors. The Report and Code Index is a listing of the report numbers of items abstracted and reviewed in the journal; this index also includes a listing of the ASQC codes for identifying the *RATR* accession numbers of the items to which the codes have been assigned. The Accession Number Index identifies the categories in which the abstract-reviews appear in the journal. Cumulative indexes are published annually.

EXAMPLES OF CITATIONS IN *RATR*

RATR ACCESSION NUMBER	R70-12733 ASQC 844; 413	ASQC CODES
	General Equipment Company, Banville, Calif.	CORPORATE SOURCE
TITLE	RELIABILITY ANALYSIS OF CHECKOUT AND SUPPORT EQUIPMENT	
AUTHOR	John A. Doe 23 Sep. 1968 27 p refs	PUBLICATION DATE
CONTRACT OR GRANT	(Contract NAS15-13411)	*TAB* AND *STAR* ACCESSION NUMBERS
REPORT NUMBER	(AD-629305; N69-15098; TR-3) Avail: CFSTI	AVAILABILITY SOURCE

RATR ACCESSION NUMBER	R70-12739 ASQC 814	ASQC CODE
TITLE	SEMICONDUCTOR RELIABILITY.	
	Joseph A. Smith (Eastern University, Arlington, Penn.).	AUTHOR AND AFFILIATION
JOURNAL REFERENCE	*Electric Journal,* vol. 8, Apr. 1968, p 478–492.	
	(A69-12569)	*IAA* ACCESSION NUMBER

RATR ACCESSION NUMBER	R70-12765 ASQC 773; 221; 823	ASQC CODES
TITLE	TESTS OF SYSTEMS WITH SOME DEPENDENT FAILURES.	
	Joseph A. Smith (Eastern University, Arlington, Penn.) and B. James White (General Equipment Company, Banville, Calif.).	AUTHORS AND AFFILIATIONS
CONFERENCE OR SYMPOSIUM REFERENCE	*Association of Reliability Engineering, Failure Rate Conference, Olney, Tex., Mar. 13–17, 1968, 8 p.* Available from Assoc. of Reliability Eng., New York: $1.00	AVAILABILITY AND PRICE
IAA ACCESSION NUMBER	(A69-12407)	

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Reliability Abstracts and Technical Reviews

A Monthly Publication

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February 1970

81 MANAGEMENT OF RELIABILITY FUNCTION

R70-14856 ASQC 810; 863; 871
INTEGRATED LOGISTIC SUPPORT AND ITS IMPLICATIONS FOR RELIABILITY AND MAINTAINABILITY
T. T. Jackson (Booz- Allen Applied Research, Inc., Bethesda, Md.) and A. Luft (U.S. Naval Applied Science Laboratory, Brooklyn, N.Y.) *In: Proceedings of the 1969 Product Assurance Conference and Technical Exhibit, Long Island, June 6–7, 1969* Conference sponsored by the American Society for Quality Control, and the Institute of Electrical and Electronic Engineers New York IEEE, Inc. p 10–16
(Contract N00140-69-D-00144)

An organized approach to the solution of logistic support deficiencies is presented. The approach incorporates the following: timely logistic support planning and funding; an engineering base for support requirements; and integration of logistic support elements in the system acquisition process. There is a continuing relationship between the disciplines of reliability and maintainability and of integrated logistic support which commences early in concept formulation and extends into operation. Integrated logistic support is dependent upon reliability and maintainability inputs for establishment of the basic concept of the logistic support system, for definition of the detailed support element requirements, for feedback and correction of the support system design in accordance with changes in the prime system design, and for evaluation of the support system design. Author

Review: This paper presents a good, brief discussion of the topic indicated in the title. The basis for it is DOD Directive 4100.35. The essential features of the relationship between integrated logistic support and the disciplines of reliability and maintainability are clearly presented in an easily-readable form. The paper will be useful to those who are interested in an overview of these relationships. The details of application to any specific system, of course, will have to be worked out.

R70-14860 ASQC 815
MIL-STD-790C—MANUFACTURER'S VIEW
John M. Hammer (Mepco, Inc., Morristown, N.J.) *In: Proceedings of the 1969 Product Assurance Conference and Technical Exhibit, Long Island, June 6–7, 1969* Conference sponsored by the American Society for Quality Control, and the Institute of Electrical and Electronic Engineers New York IEEE, Inc. p 74–78

Details are given on the management planning and organizational structure developed to comply with the quality control and reliability specifications required by MIL-STD-790C. A reliability manual was prepared to cover all facets of the manufacturing operation, and to serve as a guide for all management personnel as well as a practical working program. The responsibilities of the Reliability Committee are defined. The necessary failure analysis equipment is listed, along with the approved test facilities and the steps required for corrective action. Also discussed are the evaluation test procedures, reliability procedure training program, equipment calibration, production processes and controls, documentation, quality assurance inspection programs, audit verification inspection, material traceability system, and distributor quality requirements. M.G.J.

Review: The purpose of this paper and those by Kear and by Wilklow in the same Transactions was to discuss the implementation of MIL-STD-790C. The intent was admirable and the presentations created considerable interest and discussion. The published papers satisfy a need of industry but leave out critical reliability considerations (design details, drawing control, application notes, packaging protection, etc.) and are subject to considerable personal opinion and bias. This paper is a series of *motherhood* statements and an over-simplified overview. It is a manufacturer's interpretation of what should be done to comply with MIL-STD-790C. The author gives the impression that his organization is doing everything required. But does the organization have enough manpower, space, equipment, and research facilities? The paper does not indicate organization size, the number of people engaged in the system described, nor the cost of compliance (perhaps for competitive reasons). The author did not present the philosophy which led to management's decision to install the system to comply "with any military established reliability specification." Without some discussion of the economics involved, one is left wondering why this company does not experience the real-world difficulties which everyone else has. The paper did not discuss the system, required by MIL-STD-790C, to control "Distributor Organizations." (They are treated in the Wilklow paper.) This description of the compliance is more typical of an advertising brochure, a proposal and/or a catalogue preface, than it is a helpful technical paper. It is not recommended reading for other than promotional purposes.

R70-14861 ASQC 813; 815
RELIABILITY ASSURANCE PROGRAM FOR ELECTRONIC PARTS
Donald L. Kear (Defense Electronics Supply Center, Dayton, Ohio) *In: Proceedings of the 1969 Product Assurance Conference and Technical Exhibit, Long Island, June 6–7, 1969* Conference sponsored by the American Society for Quality Control, and the Institute of Electrical and Electronic Engineers New York IEEE, Inc. p 79–87

The procedures used by the Defense Electronics Supply Center (DESC) to manage the qualification program for established relia-

bility are explained. To verify that the MIL-STD-790 reliability assurance requirements are satisfied, the DESC qualification personnel visit the manufacturer's plant to observe complete correlation between the documented program plan and actual practice; to determine that each program element is covered in the documented program; to review and evaluate the manufacturer's control of his authorized distributors; and to conduct an in-plant semiannual review; Exit interviews are held with the manufacturer to identify and discuss the deficiencies in the reliability assurance program. M.G.J.

Review: The purpose of this paper and those by Hammer and by Wilklow in the same Transactions was to discuss the implementation of MIL-STD-790C. The intent was admirable and the presentations created considerable interest and discussion. The published papers, of which this is one, satisfy a need of industry but leave out critical reliability factors (design details, drawing control, application notes, packaging protection, etc.) and are subject to considerable personal opinion and bias. This presentation is a valuable document for parts manufacturers. It is a philosophical discussion of what the military representative will be looking for during a source evaluation visit. The specification MIL-STD-790C assumes that the manufacturer has an acceptable organization and that the design of the product and processes are adequate and consistent enough to produce a qualified product. The procedure presented by the author makes no provision for evaluating the acceptability of the design, handling and packaging, test methods and equipment, personnel training, and tolerance ranges for the characteristics of the product. Therefore one must be sure that these are adequately covered by other specifications. The paper is well done and is recommended reading for those involved with parts' manufacture. It is also suggested that the intent of the specification and subsequent evaluation procedure be reexamined to cover the missing links.

R70-14862 ASQC 815; 813

IMPLEMENTATION OF MIL-STD-790 AT A DISTRIBUTOR'S ASSEMBLY PLANT

Theodore L. Wilklow (The Bendix Corporation, Electrical Components Div., Sidney, N.Y.) *In: Proceedings of the 1969 Product Assurance Conference and Technical Exhibit, Long Island, June 6–7, 1969* Conference sponsored by the American Society for Quality Control, and the Institute of Electrical and Electronic Engineers New York IEEE, Inc. p 88–96

The evaluation of a MIL-STD-790 reliability assurance program is explained, from its initiation by a connector manufacturer through its incorporation at a distributor's assembly plant. Details are given on the procedures used by that manufacturer to control the assembly processes of the distributor and provide assurance that the specifications are incorporated. To establish these controls, certain basic requirements must be established by the manufacturer before he may consider marketing through his distribution organization. These are: (1) The distributor must have a reporting and documentation system that includes controlling the storage, handling, assembly, marking, inspection, and testing of the product. (2) Training or workshop sessions must be held to thoroughly orient the distributor with the reliability program. The distributor is then required to document his own procedures and equipment in a program plan subject to the approval of the manufacturer. Author

Review: The purpose of this paper and those by Hammer and by Kear in the same Transactions was to discuss the implementation of MIL-STD-790C. The intent was admirable and the presentations created considerable interest and discussion. The published papers, of which this is one, satisfy a need of industry but leave out critical reliability procedures (design details, drawing control, application notes, packaging protection, etc.) and are subject to considerable personal opinion and bias. Implementation of MIL-STD-790C insofar as distributor facilities are concerned is described by this paper. There are limitations to the utility of the specification and thus of all the effort being expended (see the review of the paper by Kear which precedes this one in the same Transactions). This paper does not comment on the size and capability of the manufacturer's organization needed to control distributors' quality operations. The method of auditing distributor operations would probably suffice, but is commented on in a short three paragraphs with the statement that "Continual surveillance of each assembly plant is conducted . . .". It is not apparent how this surveillance is carried out, nor are procedural guides offered to the resident or itinerant inspector. Another frequent problem not discussed in detail is controlling the application of various combinations of connectors. (However, the paper alludes to presumably adequate reliability-controlled documentation included drawings, process instructions and inspection instructions as well as assembly route cards or travelers.) How does the manufacturer assure that the distributor is assembling compatible parts for the myriad applications? How does the manufacturer determine that each possible assembly combination actually meets all the tests required by the specification? The manufacturer is responsible even though the distributor puts the items together. The forms are shown without accompanying procedural data; thus they are interesting but not very usable. This paper is important reading for comparison purposes rather than for use in originating a distributor control system.

R70-14967 ASQC 814

RELIABILITY PAYS OFF—EVEN THOUGH IT ADDS TO COSTS

Richard A. Mass *Quality Assurance,* vol. 8, no. 9, Sept. 1969 p 34–37

Improved reliability is discussed from the viewpoint that a progressive management policy on quality–reliability objectives leads to a more cost effective design production process. As reliability performance is related to the consequences of any failure, it is believed that demonstrable proof can be provided to show that practical reliability concepts contribute directly to improving the profit picture. For example, one facet of a good reliability program is a rigorous design disclosure and configuration management system, important to the money profile because it results in continuous day-to-day management attention to cost avoidance. The suggestion is made that the quality and reliability community think more in terms of making their efforts, including planning, monitoring, inspection analysis, and corrective action, more cost effective. M.G.J.

Review: Reliability engineers' activities do little good unless management approves of them and helps to enforce them. All too often, reliability activities can be carried on in parallel with and separate from the mainstream of the product and serve little else but to fulfill a nominal contractual obligation. The purposes of this paper are (1) to show engineers in what ways they can convince management that money spent on good reliability activities will be a profitable expenditure for the company to make, and (2) to give managers something concrete to help them. This is perhaps one dimension of the human factors problem of which the reliability discipline is becoming increasingly aware. In reviewing one's own reliability activities in order to recommend some to management, it is possible that some should be dropped because they are not as demonstrably successful in improving the product as are some

others. In general, the more engineering and hardware-oriented the procedure, the more profitable it is. The more statistically- and mathematically-oriented it is, the less profitable it will be. This article is not long and can be read fruitfully by those reliability engineers who aspire to be effective managers. This is true whether they are in the aerospace business, defense, industrial, commercial or what have you.

R70-14874 ASQC 817
RELATIONSHIPS AMONG POTENTIAL SORTIES, GROUND SUPPORT, AND AIRCRAFT RELIABILITY
Donald Guthrie, Jr. (Oregon State University, Corvallis, Ore.) and Edward H. Means (Pacific Technical Analysts, Inc., Honolulu, Hawaii) *Naval Research Logistics Quarterly*, vol. 15 Dec. 1968 p 491–506 1 ref
(Contract Nonr-2332(00))
(A69-16238)

A methodology is developed for assessing tactical airfield/aircraft system effectiveness, and for evaluating effectiveness changes resulting from incremental investments in ground support resources and/or aircraft reliability. Two categories of ground support functions – turnaround and maintenance – are distinguished. The measure of effectiveness is the maximum potential sortie rate achievable by the system. The methodology enables empirical derivation of the general equation of the tactical airfield/aircraft system. It also enables graphical presentation of the system tradeoffs in the form of a system analysis chart. I.A.A.

Review: Reliability is rarely a characteristic considered solely by itself. This paper shows some of the tradeoffs that can be made with respect to reliability for various kinds of aircraft situations. As the authors point out, the technique which they show in this paper is applicable for many different kinds of aircraft situations. It is relatively simple to use, assuming that one has simulation equipment available. The authors emphasize that the curves in the text hold only for one particular situation and that each person will have to generate his own set of curves. Therefore, this paper will be useful only to those who do have simulation facilities available and the knowledge of how to use them. The mathematics is quite straightforward. (Not all of the algebra was checked, but it appears to be competent.) The novelty is in deciding just which of the many calculations will be helpful and in what form to put the answers in order that they will be most convenient.

R70-14891 ASQC 815
THE CONTRIBUTION OF STANDARDIZATION TO THE RELIABILITY OF ELECTRONIC EQUIPMENT
R. W. Kersey *Microelectronics and Reliability*, vol. 8, no. 5 Aug. 1969 p 185–187

The main features of electronic equipment reliability are outlined, and the problems involved in standardizing concepts, terms, and definitions are delineated. The extent to which standardization is being achieved at the national and international levels is discussed in terms of the work being conducted by the International Electrotechnical Commission (IEC). These include the compilation of a terminology glossary, mathematical notations, and reliability data on electronic components; the inclusion of reliability clauses in component specifications; and the underlying principles of failure rate concepts. M.G.J.

Review: The title of this paper is somewhat misleading, although the contents are of interest. Essentially the paper gives a brief summary of the role of the International Electro-technical Commission (IEC) Technical Committee (TC) 56 - Reliability of Electronic Components and Equipment. These activities are mentioned by name; no specific details or sections of the reports are presented, although for British readers the names of the corresponding British documents are given. Unfortunately United States readers are in a less enviable position since they have absolutely no idea where this work is being carried on or by whom. Presumably several technical organizations such as the IEEE Group on Reliability and ASQC Electronics Division and the American National Standards Institute have contributed in some ways to the U.S. activities on this Commission, but the reports, if any, are not readily available to the U.S. electrical engineering and reliability community. For people who are interested in standardization, this article will merely whet their appetite for more. For those who are not yet concerned about these standardization activities, there will be little point in reading this article. It would have been helpful if the paper had listed some of the ways in which standards could contribute to reliability, but the discussion of the standardization activities per se is worthwhile.

R70-14895 ASQC 815; 851
A LOOK AT SEMICONDUCTOR RELIABILITY
R. S. Harm (Westinghouse Electric Corp., Semiconductor Div., Youngwood, Pa.) *Solid State Technology*, vol. 12, no. 9 Sep. 1969 p 42–46, 65 1 ref

The practical aspects of specifying semiconductor reliability are discussed. It is pointed out that the buyer should recognize the chief reasons for unreliability, the meaning of level of reliability, the inherent reliability limits of each device, and the practical economics of ordering and using one device rather than another. In the latter case, expense must be balanced with need. Statistical terms such as AQL (acceptance quality level), LTPD (lot tolerance percent defective), and MTBF (mean time between failures) are defined. A Poisson sampling plan is tabulated for testing a lot of devices with a reasonable assurance (90% confidence level) that 9 out of 10 times the number of defective units that may be found in the lot (regardless of size) will not exceed the percentage indicated by the chosen LTPD number. Ten possible causes of semiconductor failure are listed, and various test procedures are assessed. M.G.J.

Review: The object of this article was "... to discuss reliability so that the user, the supplier, the purchasing agent, the salesman and the engineer can understand ...". (It was aimed at the general user, not the very-high-reliability user.) In order to achieve this purpose, the author has taken some short-cuts in his description of statistical techniques and it is not immediately obvious that he has been successful. The phrase "lot tolerance per cent defective" is used quite often without any clear discussion of what it is. (LTPD is a common term to many quality control people but not to others.) A large portion of the paper is on the fraction-defective in a lot. On occasion, the author terms this the *failure rate*. Those who are interested in high reliability will wince at the taking in stride of 2% to 10% fraction-defectives in a lot. (In a private communication the author has stated that this fraction-defective is for the test lot only, and that lots meeting this criterion can have hazard rates of less than 10^{-5}/hr.) The author makes a very good point when he says that even though quality cannot be tested into a product, *poor quality can be processed out*. In the possible causes of semiconductor failures, he does not list poor bonds, which are regarded by some as being the major cause of defects especially in integrated circuits. In the discussion of various tests and procedures on page 45 that are available to achieve high reliability, it is not clear whether these are to be done on a sampling basis or as a screening test. In this paper, the term *inherent failure rate* is used to mean that failure rate which is reached after several weeks of burn-in and which does not decrease any further even after more burn-in. The

author says in point 8 that the seal test is not a batch operation; this is not clear since there are some tests for leakage which are done in batches. On the author's high levels of reliability, it is first of all not clear (in Figure 3) in what sense the word "theoretical" is used in the phrase "theoretical proposal." (In a private communication the author has, in effect, stated that he meant "hypothetical.") It is further interesting that even for the high-reliability diode used in the example, the highest level of reliability is apparently satisfied with [illegible]tion defectives from 2% to 5%. The listing of ten possible procedures for improving the reliability is a good qualitative summary of them. The subject of derating is treated briefly but well. The author attempts to show by means of an example that high-reliability devices are often cheaper than low-reliability devices when the lifetime cost of the equipment is considered. One of the difficulties that a producer has under these circumstances is to convince the buyer that the manufacturer really has used higher-reliability parts and that the equipment really will have lower maintenance costs rather than the claims just being sales puffery.

82 MATHEMATICAL THEORY OF RELIABILITY

R70-14854 ASQC 824; 822

INFERENCES ON THE PARAMETERS OF THE WEIBULL DISTRIBUTION

Darrel R. Thoman (William Jewell College, Liberty, Mo.), Lee J. Bain, and Charles E. Antle (Pennsylvania State Univ., University Park, Pa.) *Technometrics*, vol. 11 Aug. 1969 p 445–460 9 refs

The problems of estimation and testing hypotheses regarding the parameters in the Weibull distribution are considered. The following results are given: (1) Exact confidence intervals for the parameters based upon maximum likelihood estimators are presented. (2) A table of unbiasing factors (depending upon sample size) for the maximum likelihood estimator of the shape parameter is given. (3) Tests of hypotheses regarding the parameters and the power of the test regarding the shape parameter are developed and presented. (4) Sample sizes at which large sample theory may be useful are presented. Author

Review: Since the maximum likelihood estimators for the Weibull distribution do not exist in closed form, little has been done with regard to confidence intervals for the parameters or tests of hypotheses. The authors of this paper make use of certain pivotal functions of the maximum likelihood estimators to obtain confidence intervals for each parameter in the two-parameter Weibull distribution with both parameters assumed unknown. Also obtained are tests of hypotheses, the power of the test for the shape parameter, the bias and variance of the maximum likelihood estimators of the shape parameter, and a table of unbiasing factors. The estimators are compared with some simple point estimators which are often used in lieu of the maximum likelihood estimators. Sample sizes at which the asymptotic normal distribution becomes adequate as an approximation are also given. This is an extensive mathematical paper which makes a worthwhile contribution to reliability theory, since the Weibull distribution is of quite common occurrence in reliability data. A number of related references are cited. This paper will be of interest to those concerned with the analysis of Weibull data, as well as to the reliability theorist.

R70-14855 ASQC 824; 822

MINIMUM VARIANCE UNBIASED ESTIMATION OF RELIABILITY FOR THE TRUNCATED EXPONENTIAL DISTRIBUTION

Y. S. Sathe and S. D. Varde (University of Bombay, Bombay, India)
Technometrics, vol. 11 Aug. 1969 p 609–612 8 refs

This note derives the unique minimum variance unbiased estimate (MVUE) of the reliability function associated with the one-parameter exponential distribution which is truncated from above at a known point using the method of integral transforms. Author

Review: The authors make use of the method of integral transforms in deriving a minimum variance unbiased estimator (MVUE) for the reliability function of a truncated exponential model. The same problem was approached by another method by Holla (see R67-13463), but his work was cast in some doubt later, as the author points out in his introduction. The author is not concerned with resolving the controversy, but rather presents the solution by a different method. The relation between this result and earlier work is shown more clearly if it is put in a different form:

$$\mathrm{MVUE}\{R(t)\} = \frac{\left(1-\frac{t}{s}\right)^{n-1} + \sum_{k=1}^{[a]} (-1)^k \binom{n-1}{k-1} (1-ka)^{n-1}}{1 + \sum_{k=1}^{[a]} (-1)^k \binom{n}{k} (1-ka)^{n-1}}$$

$$+ \frac{\sum_{k=1}^{[a-t/x_o]} (-1)^k \binom{n-1}{k} \left(1-ka-\frac{t}{s}\right)^{n-1}}{1 + \sum_{k=1}^{[a]} (-1)^k \binom{n}{k} (1-ka)^{n-1}}, 0<t<x_o \quad = 0, \quad t \geq x_o$$

where the notation is the author's except that $a = s/x_o$. (s is total test time--the random variable; x_o is truncation point of population; $n \geq 1$ is number of test specimens--all of which have failed; $[y]$ is the largest integer $< y$.) When $a < 1$ $(s < x_o)$ all the sums are zero and the answer is the one derived by Pugh in 1962 (see R63-11103). Thus when the population truncation point is greater than the total test-time, the answer is unaffected by the truncation point. The author allows his estimate when $t = x_o$, but the only unbiased nonnegative estimator for $R(x_o)$ is zero. Several points need to be emphasized to the non-statistician: (1) The population itself, categorically and unequivocally, has no lives longer than x_o, no matter how many specimens are tested. (2) This is definitely not the same as censoring the testing time for an exponential population. There is a difference between censored data and a truncated population. (3) The hazard rate for the truncated population is not constant. It is continually increasing and becomes infinite at the truncation point. The true reliability function itself is not exponential. (4) Even when $x_o \to \infty$, and the true R(t) becomes exponential—this is the case usually treated, the MVUE is not exponential. This does not mean anything is wrong; so do not be disturbed. (5) The test itself is *not* censored in any way. *All* specimens are tested to destruction. Because of these five restrictions, the formula is not likely to interest reliability engineers. The mathematical derivation was not checked, for two reasons: (1) the result is correct under a special case, and (2) the correctness of the answer is of little concern to the reliability engineer because he is so unlikely to pick the distribution for his model.

R70-14858 ASQC 822; 431

EFFECT OF SYSTEM AGE ON THE DISTRIBUTION OF WAITING TIME BETWEEN FAILURES FOR SERIAL SYSTEMS

Saul Blumenthal, J. A. Greenwood, and Leon Herbach (New York University, School of Engineering and Science, Bronx, N.Y.) *In: Proceedings of the 1969 Product Assurance Conference and Technical Exhibit, Long Island, June 6–7, 1969* Conference sponsored by the American Society for Quality Control, and the Institute of Electrical and Electronic Engineers New York IEEE, Inc. p 28–51 8 refs
(Contract N00140-66-C-0759)

A methodology is given for the distribution of the waiting time between events for the process obtained by superimposing n independent renewal processes. It is pointed out that, when the number of components n is large and the age of the system t is large, the distribution in question is approximately exponential. Consideration is given to the convergence rate both as a function of system age t and of n, the system size. Expansions are obtained giving lower order correction factors to the exponential limit. An assessment is made of the relative importance of factors such as system size, system age, and shape of the distribution in affecting deviations of the waiting time distribution from its exponential limit. It was concluded that system age can cause very large deviations from the limit, and that the transient behavior of the system can be important and extend over a large time period. Author

Review: For a simple repairable series system of n components which fail independently, the distribution of time between failures of the system is approximately exponential for large values of n and large system age, t. This paper is concerned with the rate of convergence of the distribution of time between failures to the limiting exponential form as a function of t and n. It is a rather detailed mathematical presentation. The reviewer did not work through the mathematics, but did make a spot check which indicated that it was reasonable. Adequate references are cited to place this paper in perspective relative to previous work. Section 5 entitled "Practical Implications of Results" contains useful information for those who wish to use the results in the paper for the modeling of practical systems. For example, it is indicated that they have applicability to systems which are more complicated than the straightforward, simple series of elements.

R70-14859 ASQC 824

EXACT PROBABILITY LIMITS FOR LIFE TEST DATA

Satya D. Dubey (New York University, Dept. of Industrial Engineering and Operations Research, New York, N.Y.) *In: Proceedings of the 1969 Product Assurance Conference and Technical Exhibit, Long Island, June 6–7, 1969* Conference sponsored by the American Society for Quality Control, and the Institute of Electrical and Electronic Engineers New York IEEE, Inc. p 52–60 14 refs
(Contract DA31-124-AROD-338)

The proposed control chart may enable one to check if even a single ordered datum falls within the exact desired probability limits. Thus it is proposed to derive formulas for computing the exact desired probability limits for any order statistic in terms of the parameters of the known failure distribution and the percentiles of the well-known F and beta distributions. In this connection, exponential, Weibull, Weibull-gamma, uniform, logistic and several other useful distributions will be considered. Some suitable functions of several ordered data, under special cases, will also be considered for this purpose. Finally, the method will be illustrated by means of at least one suitable numerical example. Author

Review: It is often of importance to be able to tell, with a specified degree of confidence, whether the data generated by a life test do follow some assumed probability distribution. When a reasonable volume of data are available, this is often checked by plotting the cumulative data on suitable probability paper and checking for the linearity of the resulting plot. This method is not suitable for dealing with limited amounts of life test data becoming available as a test is in progress. The method proposed by the author solves this problem by making available probability limits for ordered data; these limits can be used in setting up a control chart for making decisions within the shortest possible time and with a certain desired probability. Thus the paper makes a worthwhile practical contribution to the reliability literature. The general approach is described and formulas for exact probability limits are derived for the Weibull, Weibull-Gamma, logistic, extreme value, and uniform distributions. Pertinent previous results are cited and the work is suitably documented. As the author points out, the corresponding results could be obtained for other useful failure distributions. Perhaps this and other ramifications of the topic (mentioned by the author) will receive attention later. In a private communication the author has indicated that since the publication of this paper, he has prepared a more extensive report on the same topic. Presumably he would make copies available to interested readers.

R70-14869 ASQC 824; 844

INVESTIGATION OF A RANDOM CUMULATIVE DAMAGE THEORY

A. L. Sweet (Purdue University, School of Aeronautics, Astronautics and Engineering Sciences, Lafayette, Ind.) and F. Kozin (Brooklyn, Polytechnic Institute, Dept. of Electrical Engineering, Brooklyn, N.Y.) (American Society for Testing and Materials, Annual Meeting, 70th, Boston, June 25-30, 1967) *Journal of Materials*, vol. 4 Dec. 1968 p 802–833 19 refs
(A69-15154)

A cumulative damage theory for fatigue is presented, which takes account of the randomness of the time-to-failure and of the fact that the failure process can be said to possess memory. This is accomplished by correlating the failure process with the change in hysteresis-loop area that a specimen undergoes during fatigue testing. An experimental program designed to investigate the theory is discussed. Specimens of SAE 1020 steel were tested sinusoidally, under stress control, with a mean stress equal to zero, in a tensile-compressive mode. Specimens were subjected to a single stress amplitude-to-failure, and also to mixtures of two and three amplitudes-to-failure. Hysteresis-loop areas were monitored "on-line" during all tests. The data are used to evaluate the theory, and comparisons with the Miner-Palmgren theory are shown. I.A.A.

Review: Fatigue is an important failure mechanism in aerospace structures and thus is vitally important to reliability engineers. Very rarely is a piece of equipment in the field stressed at constant amplitude, therefore the designer must use some form of cumulative theory of damage in order to estimate the fatigue behavior of this equipment. Such theories abound in the literature and most often the linear cumulative damage is used because it is so simple and tractable. But to the researcher in fatigue, investigation of new and potentially better—or more accurately descriptive—theories of cumulative damage are always a challenge and very interesting. The theory presented in this paper is such an interesting and challenging one. It is of course not possible to render a verdict of correct or incorrect on it. It assertedly gives better results in one case than the linear cumulative damage theory, but it is immensely more complicated. It is not clear what kinds of

experiments would have to be run on a given material in order that one could apply those results directly to the construction of a piece of machinery. For example, there are the various multiplicative factors to be considered due to notches. Thus this paper will be of interest and value only to those doing research (whether theoretical or experimental) in the theory of fatigue. It is not of value yet to designers. It should be noted that the term *random* refers to the life of the specimen, not to the stress amplitudes; there are theories of fatigue extant which are called random and involve stress amplitudes which are a random function of time. The authors should be encouraged to investigate their work further. It is difficult to tell when someone will come up with an extremely viable approach to this long-standing problem.

R70-14871 ASQC 824; 817

A METHOD OF ESTIMATING THE OPTIMUM MEAN LIFE OF PLANT GROUPS

J. F. Brennan (American Society of Mechanical Engineers, San Francisco, Calif.) *Journal of Engineering for Industry*, vol. 90, no. 4 Nov. 1968 p 601–608 4 refs

A method of optimizing average service life of plant groups is described. The method is stochastic or statistical rather than deterministic, in the sense that a time-frequency distribution of failures is employed. Simplified methods are introduced for determining current average life and for correlating maintenance expense with age of plant. The effects of replacement and of inflation are considered. An example of a computer solution is given. Author

Review: The techniques employed in this paper are quite different from those usually employed by reliability engineers whether they are practicing in the consumer, industrial, defense, or aerospace field. One particularly attractive feature of the method is that it uses data which are available rather than insisting that one must somehow have access to data which are not usually generated and which (as a matter of practical fact) are extremely unlikely to be generated in the future. It is not entirely clear why the author makes a brief excursion into the exponential distribution since he does not use it later on. Perhaps it is merely to show that he considers the exponential distribution not applicable. One additional use for this method which the reliability engineer would likely suggest is that it shows the kinds of tradeoffs which can be made by buying equipment which is more reliable but possibly more expensive. Reliability engineers who are concerned with various kinds of cost tradeoffs would do well to become familiar with the method in this paper and see if it does have application to their needs.

R70-14876 ASQC 824; 851

ACCELERATED FORCED TESTS

L. Ya. Peshes and M. D. Stepanova *Engineering Cybernetics*, no. 3 1968 p 31–36 6 refs

Accelerated tests in forced conditions presuppose the existence of relations transforming results of such tests to the required characteristics for service conditions. It is shown that such models can be constructed in the region E in which the physical principle of reliability holds. Author

Review: This paper is difficult to understand without the first two references being available, but it appears to show different applications when the simple theory of linear cumulative damage is appropriate. Under this theory, the rate of damage cumulation is independent of the past and depends only on the severity level of the testing. This cumulation rate is usually taken to be the reciprocal of the life at that constant severity level. Even though this translation appeared in a professional journal and is apparently not a machine translation, it was obviously not done by someone familiar with the subject. Thus, the terminology is extremely difficult to follow. Only those who are vitally concerned with not missing out on anything that is being published will need to look up this paper, and in order for it to be understood, at least the first two references will have to be available. The theory of linear cumulative damage has been especially explored in metallic fatigue where it is known as the Miner hypothesis and has been applied to dielectrics by Dakin and others (see, for example, R67-12912 and R69-14729).

R70-14877 ASQC 824; 872

A MATHEMATICAL METHOD OF ESTIMATION IN PROBLEMS OF RECURRENT EVENTS IN MAINTENANCE SYSTEMS OF TELECOMMUNICATION EQUIPMENT

Eikichi Asari (Hokkaido Telegraph and Telephone Branch Office, N.T.T., Hokkaido, Japan) *Electronics and Communications in Japan*, vol. 51-C, no. 1 1968 p 104–112 3 refs

Using the shifting probability theory for the Markov recursion process, a general numerical solution is derived for cases involving more than three failure occurrences. In the case of estimating the number of equipments operating through a given time in the future, it is necessary to consider the total number of equipments expected to be used in the future. The calculation was carried out by the trial-and-error method. This method was applied to the maintenance management of the radio relay equipment at the Telegraph and Telephone Branch Office of N.T.T. in Hokkaido. Author

Review: As the author states, this paper is addressed to an important problem from the viewpoint of maintenance. Unfortunately, however, it is impossible to read due to its cumbersome exposition, lack of precise mathematical definitions, terminology at variance with standard statistical terminology, etc. It cannot be recommended to readers in the reliability field.

R70-14878 ASQC 824; 431

THE LIMITING BEHAVIOR OF TRANSIENT BIRTH AND DEATH PROCESSES CONDITIONED ON SURVIVAL

Phillip Good (Information Research Associates, Inc., San Diego, Calif.) *Journal of Australian Mathematical Society*, vol. 8, no. 4 Nov. 1968 p. 716–722 4 refs

A transition probability matrix is presented to show that the development of a population over time can often be simulated by the behavior of a birth and death process. The limits of the conditional transition probabilities are considered, and a theorem provides existence criteria and an explicit form for the limit. Another theorem is concerned with the existence of higher moments of the conditional distribution. The relation of the existence criteria to the distribution moments of absorption times and conditional recurrence times is discussed. An integral representation is used to prove these results. M.G.J.

Review: This good paper presents some interesting results concerning limits of conditional transition probabilities in birth and death processes. Such processes are sometimes used in the modelling of system reliability. The paper will be of interest to those reliability and design engineers who wish to enhance their general knowledge of birth- and death-type stochastic processes.

R70-14879 ASQC 824

SIMPLIFIED METHODS OF CONSTRUCTION OF CONFIDENCE BOUNDS FOR SYSTEM RELIABILITY ON THE BASIS OF COMPONENT TESTING RESULTS

Yu. K. Belyayev *Engineering Cybernetics*, no. 5 1968 p 84–89 9 refs

A brief description of one of the possible approximate algorithms of construction of confidence bounds for the probability of failure-free system operation is presented. Examples presented show that the commonly used engineering method of introduction of fictitious confidence probabilities is likewise approximate.

Author

Review: The problem of estimating confidence bounds for system reliability on the basis of test data, for components has attracted the interest of reliability theorists for some time. So far, no tractable general solution for the problem has been found. However, a number of approximate algorithms have been suggested in the American and Russian literature. The author describes an algorithm, based on the general theory of γ-confidence regions, and applies it to obtain interval estimates of the reliability of composite systems. Although the general algorithm seems very tedious, involving data simulation, estimation of empirical distribution functions, and finally a gradient search for maxima and minima, an approximate solution can be found rather quickly if the parametric function of interest has an unbiased, efficient estimator which is asymptotically normal. To illustrate the method, the author estimates the lower γ-confidence bound for the probability of failure-free operation of a series chain of m independent components with exponential life, $F(t) = 1 - \exp\{-\lambda_i t\}$. In this case, the probability of failure-free operation during a time t is $P(t) = \exp\{-\sum_{i=1}^{m} \lambda_i t\}$. Assuming that truncated life tests $(N_i BT_i)$ have been performed on each component, observing d_i failures to type i components, the unbiased, minimum-variance estimator of $\sum_{i=1}^{m} \lambda_i$, $s(x) = \sum_{i=1}^{m} d_i/NT_i$, is used to form an upper γ-confidence bound for $f(\theta) = \sum_{i=1}^{m} \lambda_i$, say $\bar{f}$ yielding the lower bound $\underline{P}(t) = \exp\{-\bar{f}t\}$ for the probability of failure-free operation. The lower critical value for s(x) over all λ's $\in \Omega_f = \{\lambda's \mid \sum_{i=1}^{m} \lambda_i = f\}$ is shown to be

$$\underline{f}_{1-\gamma}(f) = \min_{\underset{\sim}{\lambda} \in \Omega_f} \{f - u_{1-\gamma} \sqrt{\sum_{i=1}^{m} \lambda_i/N_i T_i}\}$$

$$= f - u_{1-\gamma} \sqrt{f/\min_{i=1(1)m} N_i T_i}$$

The γ-confidence region is, then, that set of $f = \sum_{i=1}^{m} \lambda_i$ values such that the estimator $s(x) = \sum_{i=1}^{m} d_i/N_i T_i$ exceeds the lower critical value $\underline{f}_{1-\gamma}(f)$. Since $\underline{f}_{1-\gamma}(f)$ is a non-decreasing function of f, the upper γ-confidence bound for $f = \sum_{i=1}^{m} \lambda_i$ satisfies

$$s(x) = \sum_{i=1}^{m} d_i/N_i T_i = \bar{f}(s) - u_{1-\gamma} \sqrt{\bar{f}(s)/\min_{i=1(1)m} N_i T_i}$$

and the lower confidence bound for $P(t) = \exp\{-\sum_{i=1}^{m} \lambda_i t\}$ is therefore $\underline{P}(t) = \exp\{-\bar{f}(s)t\}$. In conclusion, the author shows with examples that the commonly used engineering practice of introducing fictitious confidence probabilities is also approximate and does not always possess the property of optimality, minimum expected length. The author compares his approach with some others which have been suggested in the Russian literature, and for which the references are cited in the paper (see, for example, R67-13480, R69-14644, and R69-14645). No reference is made to any of the American approaches to this problem. The paper is highly mathematical, and will be of interest to theorists who are following the various approaches to this problem.

R70-14880 ASQC 824; 431

REALIZATION OF A FUNCTION BY AN UNRELIABLE AUTOMATON

V. I. Levin *Engineering Cybernetics*, no. 5 1968 p 110–114 5 refs

The relationship between a function of time being realized by an automaton and its reliability is considered. For determination of this relationship it is proposed to use an operational method. This method is illustrated for a probabilistic Markovian automaton.

Author

Review: As the author of this paper points out, the design reliability of an automatic device is important only insofar as it guarantees the preservation in time of the basic engineering parameters which control the output of the device. The output is represented by a functional equation, in which the terms are functions of time associated with the input signals and the parameters of the system. The author considers deviations in the output due to perturbations in the values of input signals and perturbations in the values of the parameters of the device. The solution involves transformation of the functional equation in accordance with the operation of the device. The author considers a device with discrete states and time which realizes a simple homogeneous Markov chain. The paper consists of the mathematical solution for this particular case, and cites references to related work. This approach has practical significance since it associates the reliability of the device with its basic technological parameters. It has potential applicability to various types of devices—deterministic and random, with and without memory, with discrete or continuous states of time, etc. An important consideration is, of course, that the operational transformation must correspond closely with the actual type of operation of the device. This paper will be of interest to those who are concerned with the modelling of systems which are subject to failures of the degradation type, as opposed to those which can fail only catastrophically. Also, the necessary probabilistic characteristics of each part must be measurable if the method is to be useful.

R70-14882 ASQC 824

New Mexico Univ., Albuquerque. Mathematics and Statistics Dept.

UNIFORMLY MOST ACCURATE UPPER TOLERANCE LIMITS IN THE POISSON CASE, AND ITS APPLICATION TO INVENTORY CONTROL

S. Zacks Oct. 1968 12 p refs

(PB-183937)

Generally it is difficult to find an explicit expression for tolerance limits in the discrete parametric ease and one is tempted to use a somewhat less efficient distribution free limits. In the

Poisson case, however, an explicit expression for the tolerance limits can be derived by relating them to the corresponding uniformly most accurate one-sided confidence limit for the mean. The derived system of tolerance limits is called uniformly most accurate. The purpose of the present note is to present this idea. Upper and lower tolerance limits in the Poisson case are required statistics in various fields of applied probability, like inventory and reliability theories. The application to sequential adjustment of inventory is shown. Author

Review: As the author points out, upper or lower tolerance limits in the Poisson case required statistics in various fields of applied probability, including reliability theory. In this note, the author derives an explicit expression for the tolerance limits by relating them to the corresponding uniformly most accurate one-sided confidence limit for the mean. The advantage of these limits is that they are more efficient than distribution-free limits, for which the author cites several references. The paper consists of a concise derivation of the limits, accompanied by an application to inventory control. While this application will not be of direct interest insofar as reliability work is concerned, the derivation makes a worthwhile contribution to mathematical theory pertinent to reliability problems.

R70-14884 ASQC 824

North Carolina Univ., Chapel Hill. Dept. of Biostatics.

SIMULTANEOUS CONFIDENCE LIMITS FOR THE BINOMIAL AND POISSON DISTRIBUTIONS

Peter A. Lachenbruch Oct. 1968 86 p refs

Some results are presented on two common nonnormal distributions: the binomial and Poisson distributions. The intervals used are based on the Bonferroni inequality applied to both distributions. The approach adopted is to find the upper and lower alpha/2k points of the distribution for k equals 1, 10. An extensive set of tables is included for use in determining simultaneous confidence limits for several binomial or Poisson parameters. M.G.J.

Review: This report contains an extensive set of useful tables for specific purposes, that is, forming simultaneous confidence limits for several binomial or Poisson parameters. The tables are essentially just a tabulation of the inverse of the cumulative distribution function for the binomial and Poisson cases. They are, however, in a form especially convenient for forming confidence intervals. The author should have pointed out (and indeed emphasized) that the Bonferroni inequality, upon which the results are based, is valid with no assumptions of independence of the events under consideration. If the events are *independent* better (i.e., shorter) confidence intervals may be obtained.

R70-14885 ASQC 824

THE MOMENTS OF LOG-WEIBULL ORDER STATISTICS

John S. White (University of Minnesota, Minneapolis, Minn.) *Technometrics*, vol. 11, no. 2 May 1969 p 373–386 7 refs

Formulas are derived to obtain the means and variances of the order statistics of a log-Weibull distribution. Tables of these means and variances are included. The computations were made using a set of 100 decimal place logarithms of integers. Examples of the use of these tables in obtaining weighted least squares estimates from censored samples from a Weibull distribution are also given. Author

Review: The Weibull distribution is commonly used as a model for the time to failure and for stresses and strengths in reliability analyses. A typical problem is the estimation of the parameters of the distribution on the basis of sample data in the form of ordered failure times. The author has obtained the means and variances of the order statistics of a log-Weibull distribution for sample sizes up to 100. Tables are presented in the paper for sample sizes up to 20, and a reference is cited for the tables pertaining to larger samples. Use of these tables in obtaining weighted least-squares estimates from censored samples is illustrated. The paper is clear and detailed, and adequate references are cited for background information. It constitutes a worthwhile addition to the methodology available for estimating the parameters of the Weibull distribution.

R70-14886 ASQC 824; 541

A NOTE ON THE GAIN IN PRECISION FOR OPTIMAL ALLOCATION IN REGRESSION AS APPLIED TO EXTRAPOLATION IN S-N FATIGUE TESTING

R. E. Little and Emil H. Jebe (University of Michigan, Dearborn, Mich.) *Technometrics*, vol. 11, no. 2 May 1969 p 389–392 10 refs

(Contract DA-20-113-AMC-05927(T))

Summary information is presented on the application of optimal allocation theory for regression extrapolation or prediction to S—N fatigue testing. Consideration is given to the special cases that arise in fatigue testing such as heteroscedastic variance, and constraints due to experimental material, and time and cost limitations. Author

Review: For those who are interested in applying the theory of optimal allocation for regression to extrapolating or predicting on the basis of S-N fatigue data, this paper will serve a very useful purpose. It is not a presentation of new results, but rather a summary of results available for the following cases: (a) homoscedastic variance, fixed test time (or cost), (b) heteroscedastic variance, fixed number of specimens, and (c) heteroscedastic variance, fixed time or cost. Appropriate references in which the details of these results may be found are cited. This note serves a very useful purpose in bringing together these references for the convenience of reliability analysts.

R70-14887 ASQC 824

Weibull (Waloddi), Lausanne (Switzerland).

A GENERAL METHOD FOR ESTIMATING DISTRIBUTION PARAMETERS Summary Report, Apr. 1967–Apr. 1968

Waloddi Weibull Wright-Patterson AFB, Ohio AFML Apr. 1969 37 p

(Contract AF 61 (052)-943)

(N69-38092; AD-689405; AFML-TR-69-136; SR-8) Avail: CFSTI

The method presented is applicable to complete, censored, or truncated samples and to grouped data drawn from any population having a continuous distribution function, simple or composed, involving an arbitrary number of unknown parameters. The estimates are consistent and asymptotically efficient (in some cases for any sample size) and easily determined by use of a versatile computer program. The efficiency can be stated for any individual case, even when only a part of the sample is used for the estimation. Two criteria of goodness-of-fit, which complete each other, make it possible to decide whether the fit attained is acceptable or not. Two of its many applications may be mentioned: the evaluation of data from bending and torsional tests on brittle materials, a problem up-to-now not quite satisfactorily solved due to the complicated distribution functions arising, and the analysis of bimodal fatigue-life distributions. Author (TAB)

Review: The estimation method presented in this report consists of minimizing a weighted sum of squares of deviations of functions of the observations from their expected values. The weights are so chosen that the estimates are consistent, have minimum variance, and are asymptotically efficient. Computations are made by use of a minimum-seeking computer program. Properties of the estimates and criteria for goodness of fit are discussed in the report. Examples of application of the method to the Weibull distribution are given. This method appears to have very general applicability and yields estimates with good statistical properties. Perhaps its most fertile field of application will be in dealing with the more complex distributions such as those pertaining to the strengths of brittle materials subjected to bending or torsion.

R70-14888 ASQC 824; 550
Weibull (Waloddi), Lausanne (Switzerland).
THE EFFICIENCIES OF UNBIASED, LINEAR ESTIMATORS FOR SCALE AND LOCATION PARAMETERS COMPOSED OF ONE, TWO, OR THREE ORDER STATISTICS Summary Report, Feb. 1967–Feb. 1968
Waloddi Weibull Wright-Patterson AFB, Ohio AFML Apr. 1969 123 p refs
(Contract AF 61 (052)-943)
(N69-37136; AD-689407; TSR-2; AFML-TR-69-134) Avail: CFSTI

The result of this investivation is, from a practical point of view, important in so far as it proves that the procedure of estimating scale and location parameters can be simplified by suppressing a large part of the sample without much loss in efficiency provided that the proper ordered observations are used. These order numbers are presented for estimators composed of one, two, or three observations. It is remarkable that neglecting, for instance, 39 out of 40 observations reduces the efficiency by 35% only. The actual reduction in efficiency, being in many cases quite small when using two or three observations, can be read from the tables. Author (TAB)

Review: The results presented in this report lead to simplification of the estimation of scale and location parameters of the Weibull distribution when the shape parameter is known. The point is that the estimation may be based on properly chosen elements from the ordered sample with relatively little loss of efficiency as compared to the use of the full sample. Best order numbers, variances, and efficiencies for one-, two-, and three-order estimators are given. The estimators were derived in previous reports for which the references are cited. It should be noted that while this approach simplifies calculation with relatively little loss of efficiency, it does not drastically reduce testing time. For example, in Table 2 one finds that in a sample of size 40 the best order number to use for a one-order estimator is 32 (33 for shape parameters over 3) for an efficiency of about 66%. From the other tables it is evident that the best order numbers very often include the n*th* or (n-1)*th* of the n ordered observations.

R70-14889 ASQC 824; 431
Florida State Univ. Tallahassee. Dept. of Statistics.
RANDOM WEAR MODELS IN RELIABILITY THEORY
David S. Reynolds Mar. 1969 96 p refs Sponsored in part by the Army and AF
(Contract Nonr-988(13))
(AD-685596; M-153)

Gaver and Antelman and Savage have proposed models for the distribution of the time to failure of a simple device exposed to a randomly varying environment. Each model represents cumulative wear as a specified function of a nonnegative stochastic process X with independent increments, and assumes the reliability of the device is conditioned upon realizations of this process. From these models are derived the corresponding unconditional joint distributions for the random failure time vector of n independent, identical devices exposed simultaneously to the same realization of the wear process. Conditions are given under which both models can give rise to identical one-dimensional failure time distributions. Joint failure time distributions are obtained in explicit form and the probabilities of ties and tie configurations are derived. Maximum likehood estimates are obtained for certain relevant parameters for each of the models when X(t) is a process with stationary nonnegative increments. TAB

Review: This report extends the work of Gaver (see R63-10851) and Antelman and Savage (see R67-13095) on stochastic wear models in reliability theory. It is a long detailed mathematical treatise which will be of interest only to the theorist who is working with stochastic processes. For this reason no attempt was made by the reviewer to check the mathematical details; the approach appears sound and there is no reason to doubt the competence of the work. As far as reliability engineers are concerned, more down-to-earth examples need to be given before theory such as this will be usable. It would be worthwhile for someone to try to bridge the gap between theory of this kind and practice.

R70-14892 ASQC 824
A SIMPLE GUIDE TO THE GENERAL ASSESSMENT OF MTBF
C. G. Deakin (Scientific Instrument Manufacturers' Association, London, England) *Microelectronics and Reliability*, vol. 8, no. 3 Aug. 1969 p 189–203
(A69-39700)

Outline of a simple method for determining the mean time between failures (MTBF) at a given confidence level for the total unit test hours to which a component, equipment, or system was subjected. Two alternative or supplementary systems are devised. The first system uses a table of factors at various confidence levels, for zero and n number of failures. The second system uses 11 graphs in which total unit test hours are numbered from 1 to 1000, and the confidence level slope commences at 100 unit test hours in each case. Examples of practical applications of both systems are presented. I.A.A.

Review: This paper is an extreme example of the cookbook approach to assessment of reliability. One is merely given a table of factors or set of graphs and told that of the four things (confidence, number of failures, total test time, MTBF) if three are known, the other can be calculated. There is absolutely no indication of the theoretical assumptions that go into the theory used. In fact, on page 189, it is easy to infer that these factors were empirically derived, whereas, of course, if they are to mean anything, they must come from some theoretical formula. There is no indication, of course, of how the formula was derived, but apparently the distribution of times to failure is considered to be exponential. The total test time is fixed for any given test and the number of failures is the random variable. The confidence indicated is statistical confidence which has a very specific, technical meaning. Unfortunately, the meaning of statistical confidence is little appreciated by engineers, largely because the more exactly it is understood, the less appropriate a concept does it become for them to use. Roughly speaking, the confidence level is the fraction of times one will get a true statement if he goes through a certain statistical procedure to get an answer. The confidences listed in the text are lower bounds; that is, the confidence will be the number given in the table or some greater number. This is due to

the fact that the random variable is discrete, namely, the number of failures. It is possible to derive also an upper bound on the confidence. Table 1 is the ratio of true MTBF to total test time (according to the test) and thus, for the conditions stated, it should be 2/ chi sup 2 sub alpha (2n+2) where the item within parentheses is the number of degrees of freedom of the chi-square distribution and alpha is the per cent listed in the table (the right-hand tail area of the chi-square distribution); the table was spot-checked—no errors were found. None of the graphs were checked, but they are presumed to be based upon the table. The theoretical assumptions which give rise to the kind of behavior calculable by these tables are the following: (1) assume that the equipment has been in operation long enough so that one can calculate the average time between failures very closely. Assume that this number is then known exactly. (2) At any given instant in time, the time interval to the next failure is completely independent of any observations made on the equipment in the past. For example, one does not care when the previous failure occurred or what kind of failure it was. Another way of stating it is that a man who knows the failure behavior of this equipment for the past several failures is in no better position to predict the instant of a new failure than is a person who just arrives upon the scene and is given only the number mentioned in (1). The descriptions in the text of how to use the charts and tables are barely adequate. Persons who are not adept at handling charts and graphs might not be able to interpret the instructions.

R70-14896 ASQC 824
PREDICTION BY SAMPLING

Bruce Galbraith (Fairchild Semiconductor, Mountain View, Calif.) *Solid State Technology,* vol. 12, no. 9 Sep. 1969 p 47, 48

To predict the distribution of chips on a silicon wafer, a two-dimensional matrix is used to represent two electrical parameters of semiconductors. The binomial probability distribution theory is then used to predict the distribution of units in the lot. Author

Review: The author is trying to explain a very conventional statistical concept and has been only moderately successful. The concept is that from a sample one can estimate the true parameters well enough under many circumstances. The problem considered is that of trying to estimate the fraction of the population which occupies a cell in a two-dimensional array. It is not at all obvious why the author insists on its being a two-dimensional array; it could be of any number of dimensions and not affect the theoretical development at all. He uses the Gaussian approximation to the cumulative binomial distribution without indicating that it is an approximation nor indicating any of the corrections that are sometimes made in order to improve the approximation. In the nomenclature list, the author states that "p is the actual per cent of units that fall into a particular cell." Rather than *actual per cent,* he means *true fraction,* and it would be worthwhile calling this an *unknown parameter.* In the author's situation, a two-sided confidence interval would apparently be better than a one-sided confidence interval but he does not mention it. In the table giving sample results 15% of them are unaccounted for. The sentence on page 48 which states that ". . . it can be determined that 95% is the lower confidence bound of p for each cell . . ." is obviously incorrect, but the table itself is correct. In the next paragraph, the statement ". . . if $\hat{p}$ equals .10, then 95% of the time p is at least 6.5%." is also not correct: it does not use statistical confidence correctly.

83 DESIGN

R70-14857 ASQC 831; 871
SEPARATION OF MAINTENANCE AND OPERATOR ERRORS FROM EQUIPMENT FAILURES

M. J. Kirby and R. L. Klein (Sperry Rand Corp., Sperry Gyroscope Div., Great Neck, N.Y.) *In: Proceedings of the 1969 Product Assurance Conference and Technical Exhibit, Long Island, June 6–7, 1969* Conference sponsored by the American Society for Quality Control, and the Institute of Electrical and Electronic Engineers New York IEEE Inc. p 17–27 1 ref

The fact that imperfect maintenance can contribute significantly to degradation of system effectiveness is presented, as well as a description of an analysis precedure which has been used successfully for a number of years on one complex avionics system. Symptom histories are displayed; symptom patterns identify errors in diagnosis, errors in repair action, operator errors, and equipment failures. Applications to other systems, including civilian applications, are cited. Author

Review: It is about time someone was able to document, analyze, study, and evaluate a cancerous effectiveness problem—congratulations are due the authors. Needless to say the thesis and subjective treatment of this topic is most timely and welcome. The authors discuss Symptom Pattern Observation Technique (SPOT) which functionally attempts to isolate problems caused by inadequate maintenance. The system is cumbersome and will presumably be simplified as experience is gained in using it—but it works and could be valuable to almost any maintenance operation involving a system. The only parts of the system that could be questioned are the conclusions reached by the analytical segment of the system. The authors appear to assume that defects (reported by a user) which are not repaired by the maintenance function are the fault of the personnel providing the function. (See note at end of this review.) The assumption may be justified but is not defended in the presentation. This reviewer would also question the adequacy of test equipment, diagnostic procedures, operating indicators as well as the maintenance personnel. Basically, it is difficult to accept the conclusion that the maintenance equipment may not be a contributing factor in defective or potentially defective items being overlooked, not repaired, and put back in service. The further application of the method should include the assignment to maintenance engineers of the task of developing more sensitive diagnostic equipment/procedures. Although some terminology and definitions in this paper are confusing, because they do not agree with published standards, it is easily deciphered and the message is clear and well documented. Maintenance engineers, reliability engineers, and program managers are encouraged to read this paper and apply the philosophy to their own products. In a private communication the authors have commented as follows. "The paper as written seems to say that we assume that maintenance errors are personnel errors. We did not intend it that way; in fact, our intention was to the contrary. . . . (In) another paper, 'Measuring Maintenance Effectiveness', (which we) presented at the S.O.L.E. National Convention in 1968, the 'Discussion' section mentions '. . . the improvements in test equipment, manuals, training, and other elements of logistics which are often vitally needed . . .' . . . . An earlier paper, 'Mission Effectiveness with Incomplete Maintenance', given at an IEEE 'EASTCON' Convention in 1967, . . . contains a number of equations not given in the paper which was reviewed, and which describe the flow of symptoms and failures."

R70-14866 ASQC 833
SPACE RELAYS—DESIGN CONSIDERATIONS FOR RELIABILITY
Donald M. Papa (Cutler-Hammer, Inc., Milwaukee, Wisc.) *In: Proceedings of the 1969 Product Assurance Conference and Technical Exhibit, Long Island, June 6–7, 1969* Conference sponsored by the American Society for Quality Control, and the Institute of Electrical and Electronic Engineers New York IEEE, Inc. p 175–182 5 refs

Reliability requirements for electromechanical space relays, as specified in MIL-R-6106F, are hermeticity of the relay enclosure, fault current capability of the contacts, surety of operation of the electromagnet, and vibration resistance of the contact structure. For maximum reliability, sealing by either electron beam or tungsten inert gas welding is preferred because of its higher temperature capability and reduced contamination potential of the enclosure interior. A knowledge of the duration the enclosure is exposed to deep space is considered important for determining the maximum leak rate permissible. Other recommended design considerations include: (1) The minimum contact forces must always be greater than the maximum constriction force. (2) To retain normal relay operation, a diode-transistor should be used. (3) Vibration resistance in a relay is best obtained by designing the various components to have natural frequencies outside the high vibrational energy envelope of the application. M.G.J.

Review: This paper is a discussion of the reliability considerations involved in the design of electromechanical relays for aerospace applications. As such, it will be of interest to the designers of such relays rather than to those who design aerospace equipment using relays. Topics considered include the hermeticity of the relay enclosure, fault current capability of the contacts, surety of operation of the electromagnet, and vibration resistance of the contact structure. The discussion is reasonably detailed and well illustrated. It appears to be based on the requirements of MIL-R-6106F, and consequently will be of interest to those concerned with the design and manufacture of relays in which this specification must be implemented.

R70-14868 ASQC 833; 844
FASTENING AND JOINING, FIFTH EDITION
Robert L. Stedfeld, ed. *Machine Design*, vol. 41, no. 21 Sept. 1969 p 1–332

Fastening and joining technology is surveyed emphasizing techniques for selecting and applying most types of fasteners; assembly equipment; welding, brazing, and soldering processes; and adhesives. A comprehensive directory is included containing manufacturers data on screws, bolts, and studs; nuts; inserts; washers; pin fasteners; rivets, eyelets, and staples; retaining rings; quick-operating fasteners; assembly equipment; welding, brazing, and soldering; and adhesives. E.C.

Review: Reliability is an engineering problem and is often referred to in its essence as attention to detail. This entire issue is devoted to fastening and joining and shows the kinds of details to which engineers must pay attention. It is from this kind of reference that many preliminary selections are often made. (No attempt was made to assess the accuracy of the entire issue, but a spot check showed high quality of the discussion.) The experienced designer perhaps does not need to be reminded of the critical role which fasteners and joining methods play in reliability, but the person just out of school often thinks of a welded joint as simply a welded joint and a bolt as a plain bolt. For the neophyte, this reference can be used almost as a textbook to inform him of the myriad of details about which his attention will be required and of whose existence he was previously probably not even aware. It would be nice to see more explicit emphasis on life of the parts, especially with numbers, in order that the importance of life may be brought home again and again to designers. Perhaps future issues can be modified in this direction.

R70-14873 ASQC 830
RELIABILITY CONSIDERATIONS IN DESIGNING INDUSTRIAL CONTROL COMPUTER SYSTEMS
H. A. Spivak and L. E. Hawkins, Jr. (Honeywell Inc., Computer Control Div., Framingham, Mass.) *Computer Design* Nov. 1968 p 34–42

Basic system reliability requirements are discussed from the viewpoint that such considerations must be an integral part of the initial circuit, thermal, and mechanical design of any industrial control system. The tools which the design engineer has at his disposal are cited as (1) simplify the design to a minimum of parts without degrading performance; (2) perform reliability design reviews by means of reliability analysis; (3) apply component derating techniques to the best possible advantage to reduce failure rates and to increase component life; (4) reduce the operating temperature of components in the equipment by providing heat sinks, appropriate packaging, and adequate cooling; (5) eliminate resonant vibrations by proper isolation, and protect equipment against shock, humidity, corrosion, etc.; and (6) perform rigorous prototype tests and specify thorough production equipment test procedures. Author

Review: This is a good elementary discussion of reliability considerations and beginners in the field of reliability can profit from reading it. It is important to remember that papers such as this do not tell engineers anything with which they will not agree, and much of the time, engineers are all too prone to say yes, yes, yes, that's the way things get done, that's the way they ought to get done. Unfortunately, with the press of schedules, costs, and bosses, and personal foibles, a lot of these things will not get done unless the system is set up to ensure that they will. The authors wisely stress a considerable number of reliability reviews from the concept stage until completion. The object of all of this is to pay as much attention to detail as possible so that there are no failures about which someone could say, "Of course that failed, we forgot to do something we should have done." Two points which the authors did not bring out but which are important in the context of the article are the following. (1) Switches and relays and other devices employing electrical contacts are extremely difficult to derate. It is not a simple matter of using contacts with a larger voltage or current rating. This is an even more difficult situation than the electrolytic capacitors (mentioned by the authors) since in that case at least a nominal derating does no electrical harm, whereas with electrical contacts one can actually be worse off by performing a nominal derating. (2) While worst-case analysis and required performance may appear to be wasteful and overly conservative design, many people, especially when designing for industrial use, have found that this extra margin of safety is worthwhile because of the multitude of factors which did not get considered in the analysis. In the final field use of the item, one is often extremely glad that the safety margins provided by worst case were actually provided in the system. One should remember that he never analyzes the hardware itself; he analyzes only a conceptual model of that hardware. All in all, this is a good paper, and even those who think they are experts in reliability will do well to read papers such as this occasionally to be sure they are not forgetting anything.

R70-14875 ASQC 831; 844; 873

RELIABILITY AND MAINTAINABILITY ANALYSIS OF A TWO YEAR MANNED SPACECRAFT MISSION

Hugh A. Jennings (The Boeing Company, Space Div., Seattle, Wash.). *Journal of Spacecraft and Rockets,* vol. 6 Mar. 1969 p 1–8 2 refs
(Contract NAS-9-6816)
(A69-26797)

A study was performed to determine if it was practicable to accomplish a combined mission in earth orbit that could be used to develop a significant segment of a Mars mission spacecraft while conducting an earth-orbital experiment program. Part of this study involved a reliability and maintainability analysis of the combined mission spacecraft to establish the requirements for a 99% probability of mission success for 730 days. The primary analysis method was a computerized mathematical model which selects redundancy and spare alternatives to supplement a basic single thread system. A mission simulation model was used also to evaluate the spacecraft unscheduled maintenance requirements. I.A.A.

Review: It is worthwhile for theorists to read occasionally about what designers are actually doing and the techniques that they are actually using in their designs and analytic procedures. In this paper, the statistical sophistication is very low; exponential distributions are used for times to failures—lognormal distributions for maintenance repair times. One of the general reasons for not using more sophisticated techniques is that there are not enough data to support them. The actual calculations are complex enough because of the tremendous number of components so that no one goes around looking for trouble, especially when the benefits of other more complicated techniques are nebulous at best. This paper shows that for very long missions, the concept of redundancy is virtually equivalent to that of some kind of maintenance, therefore the particular maintenance method selected is a vital part of the reliability analysis. The analytic techniques seem quite straightforward. While apparently many engineering judgments were made (and individuals might differ on those judgments), they are not unreasonable. As more information is accumulated on the kinds of things that go wrong in space missions, for example, the Apollo shots, the calculations such as these can be refined. All in all, this is a good paper, and reliability engineers in the aerospace business should be familiar with the kinds of analyses actually being performed. Two references which summarize this paper are [1] and [2].

References: [1] "Maintainability and Reliability of Environmental Control/Life Support Systems," Hugh A. Jennings, presented at the Aeronautic and Space Engineering and Manufacturing Meeting, Los Angeles, Calif., 7-11 Oct 68, SAE Paper No. 680745 (Society of Automotive Engineers, Inc., 485 Lexington Avenue, New York, N.Y. 10017). [2] "Reliability and Maintainability Analysis of a Two Year Manned Spacecraft Mission," Hugh A. Jennings, presented at the AIAA 5th Annual Meeting and Technical Display, Philadelphia, Pa., 21-24 Oct 68, Paper-1059.

R70-14890 ASQC 830

ON THE IMPLEMENTATION OF FAILURE-TOLERANT COUNTERS

Jochen Beister (Karlsruhe University, Karlsruhe, Germany) *IEEE Transactions on Computers,* vol. C-17, no. 9 1968 p 885, 886 3 refs
(Contract T 590-K-203)

A new method of designing and implementing intrinsically failure-tolerant counters with error-correcting state assignments is proposed. Threshold logic elements are used, and state recovery circuitry is united with the flip-flop input logic. A decimal counter built according to this method requires considerably fewer components and has a lower probability of failure at less cost than a diode logic version. Author

Review: This short note is very worthwhile. The author has done a fine job of putting the work of R. L. Russo [1] into practical form and extending it to the useful BCD and hexadecimal examples. In addition, the improvement in cost and size which results from the use of threshold logic is very interesting. The mathematical work is done and the realizations presented for these most common examples, so that the note will save a lot of work for the person wishing to employ this efficient method of improving counter reliability. It is a very valuable extension of Russo's work. In a private communication, the author has provided the following additional information. (a) Further investigation has shown that the type of failure-tolerant counter described in this paper can compete with a triplication approach only if the output is required to be in 1-out-of-N form. For those who read German, this work is described in another paper, "Ausfallsicherung bei sequentiellen Schaltungen," reprints of which are available from the author. (b) Extension of the threshold element approach to sequential circuits of a more complicated structure (e.g. shift registers) leads to prohibitive cost when compared to triplication. The reason is that majority vote taking can be performed on the outputs of three independent units, whereas the threshold decoding scheme has to protect the internal functioning of a single structure made more complicated by the error-correcting coding of its internal states.

Reference: [1] R. L. Russo, "Synthesis of error-tolerant counters using minimum distance three state assignments," IEEE Transactions on Electronic Computers, vol. EC-14, pp. 359–366, June 1965.

R70-14893 ASQC 838; 883

FAULT INDICATORS AND THE UNAVAILABILITY OF REDUNDANT CIRCUITS

C. S. Repton (University of Birmingham, Electronic and Electrical Engineering Dept., Birmingham, England) *Microelectronics and Reliability,* vol. 8, no. 3 Aug. 1969 p 215–234 16 refs

The effects of two types of fault indication schemes on the unavailability of redundant circuits are considered. Expressions are derived to predict the unavailability of the redundant circuit as the efficiency of the fault indication scheme varies. It is shown that the usual assumption that repair is started as soon as a fault occurs can seriously overestimate the reliability of a system if the fault indication scheme is not working efficiently. The equations can also be used to obtain the conditions required for an efficient indication scheme. The results of some simulation studies are included. Author

Review: This is a good discussion on the practical problems associated with fault indicators and redundant circuits. The author very properly cautions against the irresponsible uses of the model and describes each one of the models quite well so that its applicability to any given situation can be ascertained. The figure-of-merit used largely throughout the paper is *availability in the steady state.* One of the author's main themes is that the upper bound on reliability (calculated by assuming that repair starts instantaneously with failure) is often much too high, and that the time interval between failure and the start of repair often appreciably reduces the availability. A knowledge of probability and Laplace transforms is essen-

tial for understanding much of the paper; however, the results themselves can be understood with ordinary college mathematics. This kind of treatment of the problem is not often made in the literature; thus this article will be valuable for design and reliability engineers. The mathematics was not checked in its entirety, but it appears to be competent.

84 METHODS OF RELIABILITY ANALYSIS

R70-14870 ASQC 844; 775

HEAT FINDS FATIGUE CRACKS

Edward J. Kubiak (General American Transportation Corp., Research Div., Niles, Ill.) *Metal Progress*, vol. 94, no. 6 Dec. 1968 p 131–133

(A69-24262)

Discussion of dynamic infrared inspection by means of which fatigue cracks in aircraft and missile structure can be detected from a distance of 6 ft. Fine defects are revealed by variations in IR energy. Picked up by a radiometer from the surface heated by a xenon arc lamp, these variations are recorded for analyses. By replacing the arc lamp with a CW laser, distances up to 30 ft can be achieved. Author

Review: High reliability, especially in aerospace structures, requires periodic inspection in order to detect cracks (usually caused by fatigue). This is a tedious, difficult task, and sometimes cracks have to grow to an almost dangerous size before they can be detected. The procedure described in this paper may alleviate that situation somewhat. It is not clear from the description how much field experience there has been with the method, but its potential is high enough so that it is worth trying. Area scan methods such as this are, of course, most easy to use when the areas of very high probability for fatigue cracking are selected for scanning and the others ignored. There are other methods of detecting fatigue cracks, such as eddy currents induced in the surface; no mention is made of the sensitivity of this infrared method as compared to that of the other more well-known techniques. This paper was abstracted from "Dynamic infrared detection of fatigue cracks," presented by the author and associates at the 5th International Conference on NDT, Montreal, Canada, May 1967. The original paper includes the comparison mentioned above.

R70-14872 ASQC 844; 782

HEAT DISSIPATION IN ELECTRONIC EQUIPMENT

G. Payne (Marconi Co. Ltd., Aeronautical Div., Basildon, Essex, England) *The Marconi Review*, vol. 31, no. 171 1968 p 265–281

Formulas are presented for direct calculation of heat dissipation; these are restricted in use to ambients of −55 C to +55 C and temperature rises up to 50 C. The formulas also assume that the outer skin of the unit is made of good heat conducting material, not thicker than 1/16 in. These formulas may be used for the case of the totally enclosed unit, the self-ventilated unit at ground level, forced ventilated unit at ground level, forced ventilation at any altitude, transistor heat sink in still air, transistor heat sink in moving air, and forced ventilated unit at ground level with cooling air below ambient temperature. The actual derivation of the formulas from the empirical and heat engineering information is described in general terms. M.G.J.

Review: High temperatures are often the enemy of reliability for electronic equipment, but, as the author points out, many calculations of temperature rise can be extremely difficult unless one has at hand a fount of empirically derived numbers for heat transfer. The author's philosophy is very good; he supplies several "quick and dirty" formulas so that engineers can make calculations of temperature rise for their equipments. He uses the watt for heat, rather than BTU's or calories, to further simplify the calculations. These calculations are often the best that can be done during early design stages, and they are important since thermal effects are very often neglected at this stage. The author points out that these calculations can be refined later as more knowledge about the equipment is derived, but he also correctly points out that rarely will anyone do this. The equations themselves were not checked, but their derivation is competent. This technique is recommended to reliability engineers and designers who do not have something equivalent at hand. It is much more important to make approximate thermal calculations than it is to put off any calculations because they would not be sufficiently exact. In a private communication the author has stated that the figure of 0.215 on p. 276 should read 0.19 in the light of experience; this will have the effect of changing the constant 6.7 to 6.0 throughout the paper. He has also indicated that the asterisk at the bottom of p. 276 should read: "31.5 is the constant to convert one BTU per degree F to watt minutes per degree C."

R70-14883 ASQC 844; 830

COMMON MODE FAILURE CONSIDERATIONS IN THE DESIGN OF SYSTEMS FOR PROTECTION AND CONTROL

E. P. Epler *Nuclear Safety*, vol. 10, no. 1 Feb. 1969 p 38–45 5 refs

A failure of instrumentation in the control system can initiate the need for reactor protection. If the same circumstances also can induce failure of the instrumentation that was provided to protect against the control failure, a potentially hazardous situation exists. Similar, or particularly identical, instruments are susceptible to such common mode failures. Examination of simultaneous failure incidents in reactor protection systems indicates that the use of identical channels of instruments is only marginally acceptable for protection alone. Identical channels in both the protection and control systems are unacceptable if protection against failures of the control channels is provided solely by the identical channels in the protection system. Author

Review: The basic point which is addressed in this paper is that when a group is made up of identical elements, all in the group would respond similarly to an externally applied stimulus, and, if failure resulted, this would be a common mode failure. The paper is concerned specifically with common mode failures in the control and protection systems of nuclear reactors. These systems depend heavily on identical redundant systems with repair. Failures of separate elements due to common causes can occur in space vehicles also; therefore the principles which are discussed in this article have application in the design of aerospace systems. In assessing the reliability of any system, it is important to keep in mind the possibilities of common mode failures, which, if neglected, could lead to erroneous results in calculating the benefits of redundancy. All of the underlying assumptions need to be kept clearly in mind and situations must be evaluated for the presence of factors which could produce changes in characteristics of components,

unrecognized dependence on common elements, the possibility of disablement by various types of accident, and the possibilities for human error. (The author in a private communication has pointed out that human error is more than a possibility and deserves more emphasis.)

R70-14894 ASQC 844
SYSTEM RELIABILITY IN TELEPHONE SWITCHING EQUIPMENT
J. P. Ronayne (Standard Telephones and Cables; Ltd., London, England) *Microelectronics and Reliability*, vol. 8, no. 3 Aug. 1969 p 239–242 7 refs

The reasons which lead to inaccuracy in reliability estimates are discussed, along with the problems involved in obtaining reliable component failure rates. Two developments in the manufacturer—customer relationship are cited as efforts to improve the situation. These are: (1) The increasing use of system effectiveness studies by the manufacturer in his offer, and by the customer in evaluating offers, reduces the criteria required of a system to numerical terms for evaluation. (2) An increasing number of manufacturers underwrite their estimates of customer satisfaction by risking some or all of their profits on a contract. Mention is also made of the national and international work being done to standardize component specification, testing, and test reports. M.G.J.

Review: One's reaction to this paper will depend largely on whether the information is new to him or not. Probably, if he is not familiar with the distinctions and difficulties brought out, he will be impressed favorably with the paper. If he is already familiar with those things, he will probably wonder why the paper was written and published. The title is not very descriptive. The major portion of the paper is taken up with the uncertainties involved in a reliability prediction. Some of the terminology is awkward, especially in the curves for a redundant system. Thus, this paper can be recommended for reading only to those who are not aware of the difficulties involved in such reliability estimates.

R70-14897 ASQC 844
ANALYSIS FOR IMPROVED RELIABILITY OF FLUID SYSTEMS
S. R. Tyler (Dowty Fuel Systems Ltd., Cheltenham, England) *The Quality Engineer*, vol. 33, no. 4 Aug. 1969 p 10–21

An engineering-directed reliability program for hydro-pneumatic equipment with industrial applications is discussed on the basis of experience gained from an aircraft gas turbine fuel system reliability program. Determination of the relationship between the mean time between failure and the time between overhaul is basic to the program as well as attaining sound basic design of components. Other program criteria to be monitored are maintainability, rig testing and operating performance, and use of standard production parts. Wear, environmental effects, and the failure potential of seals and flitration parts in fuel systems are examined. Test facilities for reliability and performance assessment are mentioned. E.C.

Review: This is generally a good paper especially as far as the engineering comments are concerned. It treats reliability largely within an engineering framework (as opposed to a statistical framework), which is very good. There is, however, some difficulty which arises perhaps because of the British vs. U.S. way of expressing some of these ideas. There are several places that are not clear. The statistics itself is very difficult to interpret, e.g., ". . . therefore failures are included in the defect rate and must be better than 10 sub 5", "failure rate must be better than 10 sub 8." MTBF's are given, for example, as "0.2 per thousand hours." Certainly the latter in the United States would be called a failure rate (hazard rate) rather than an MTBF. MTBF (mean time between failures) certainly implies a measure of time. Unfortunately, the large sketch (Figure 11) is very poorly reproduced and conveys virtually no information. Much of the emphasis in the paper is good. For example, "Once developed, this type of valve is not so expensive to produce, quality control is easier, and the danger of jamming is substantially eliminated." In some places, it is implied that there is no obligation on the part of a designer to try and make things foolproof (second column, page 11), but perhaps this was inadvertent on the part of the author. As is customary in much of the literature (but unfortunate nevertheless), the word *random* is used to imply a Poisson process, whereas, of course, all the word really means is that the variable is subject to chance. The word *random* does not imply any particular probability distribution.

R70-14898 ASQC 844
THE EFFECT OF MEAN STRESSES ON FATIGUE STRENGTH
R. D. C. Passey (Rolls-Royce, Ltd., Derby, England) *Aircraft Engineering*, vol. 41, no. 7 Jun. 1969 p 26–29 7 refs
(A69-34197)

Description of a new type of empirical alternating/mean stress diagram for plain fatigue specimens. The diagram is shown to combine the merits of the modified Goodman line and the Gerber parabola, with increased accuracy. An appendix contains a comparison of test data for three aluminum alloys. Author

Review: Fatigue is a common failure mechanism for many aerospace structures (as well as other metallic structures of course). In the traditional analysis of a fatigue spectrum, it is necessary to find the effect of various mean loads on the life of a part. There are usually two reasons for this: (1) to calculate an equivalent spectrum for cumulative damage, and (2) to find the fatigue life of parts where a considerable preload exists such as a bolt. The traditional means for doing this are the Gerber or Goodman diagrams and various modifications of each. This author is suggesting that these traditional diagrams sacrifice accuracy for convenience, and can give dangerously optimistic results in certain circumstances. He is using the term *mean stress* in the sense of *mid-range stress* (as is common in the literature). The term *mid-range*, which means one-half the maximum plus minimum, is better than *mean*, which in a mathematical sense is often taken to be the time average of the stress; the latter is definitely not meant. His analyses of many experimental data show that an excellent approximation to the actual curve can be obtained by using three straight lines, and they are constructed as follows. Alternating stress amplitude is the vertical coordinate; mean stress is the horizontal coordinate. The first line begins on the *alternating stress amplitude* axis at the fatigue strength point and aims toward the point on the *mean stress* axis which is the true tensile strength (actual load at failure divided by actual area at failure, this is equivalent to the maximum notched tensile strength). One continues down this line until the peak stress is equal to the stress at 0.1% or 0.2% elongation (the author is not clear on which one of these points is to be used). The curve then heads toward the *mean stress* axis at a point 1/3 of the way from the nominal strength toward the actual strength (2 times *nominal* plus *actual*, all divided by 3). It continues in that direction until it reaches a point where the peak stress equals the nominal tensile strength. It then follows the line of *peak stress* equals *nominal tensile strength* on down to the *mean stress* axis. The author arrived at his conclusions by drawing the best line through test points obtained from constant load range fatigue tests. Cumulative damage and scatter were not discussed. He has picked the con-

struction of this curve so that the necessary data points are readily available, and thus the line is constructed even from a most meager set of data. For ease in construction, it can be noted that any line of constant peak stress has a slope of −1 and intersects the horizontal axis at that peak stress.

R70-14899 ASQC 844
SEMICONDUCTOR WHODUNIT: WHO'S TO BLAME FOR FAILURES ?
Owen Doyle *Electronics*, 18 Aug. 1969 p 97–101

The lack of quality control by semiconductor manufacturers, and the system failures which such defective devices cause, are discussed. Competitive price wars, and the profit motive are cited as the main reasons for by-passing microscopic examinations or electrical equipment tests. The failure analysis laboratories established by some system makers, and the QRC (quick reaction capability) group formed at the Rome Air Development Center are described in terms of test techniques and the defects which cause failures. Several examples are given to show that visual inspection is less than adequate, if not nonexistent, at the vendor level. M.G.J.

Review: This is a good paper on what is wrong with many of the semiconductors that are shipped to customers. The paper itself is not really addressed to the title although the problem does occupy a few paragraphs. The paper is concerned largely with some of the failures that have appeared and the fact that most of them are traceable to obviously poor processing or design on the part of the manufacturer. As to who is responsible, there are various levels on which the question can be answered. At one level, obviously, the designer is responsible since he did not specify the screening test to which each transistor should be subjected. On another level, if any of these transistors are being shipped in violation of one of the specifications, the manufacturer is clearly at fault. Of course, in between the designer and manufacturer, there are a great many people such as purchasing agents and contract officers and bosses (on both sides) who can aggravate an already difficult situation. The paper is recommended reading for anyone who uses, specifies, purchases, makes, or sells semiconductors, whether they are commercial, industrial, consumer, defense, or NASA oriented. The customer must often put in several specifications which will prevent his getting less than he would expect on the basis of the manufacturer's sales literature. (It has been pointed out that a typographical error resulted in a word being left out on p. 100 in the paper. Line 9 in column 2 on that page should read: ". . . which could result in metal *opens* at oxide steps . . .".)

R70-14900 ASQC 844
ANALYZING FRACTURE CHARACTERISTICS BY ELECTRON MICROSCOPY
Austin Phillips and Victor Kerlins (McDonnell Douglas Corp., McDonnell Douglas Astronautics Co., Santa Monica, Calif.) *Metal Progress*, vol. 95 no. 5 May 1969 p 81–84
(A69-28181)

Description of the use of the electron microscope in fractographic studies to determine the causes of service failure. Processing and material defects illustrated by optical and electron microscope are presented, including grinding cracks, quench cracks, hydrogen flakes, hydrogen embrittlement fractures, flow-throughs, cold shuts, seams, inclusions, and porosity. Author

Review: This is a brief well-written article describing fracture surface characteristics associated with various causes for service failure. Failure analysis, and the consequent feeding back of the results to design-production groups, is an essential technique for achieving high reliability. Both optical macrographs and electron fractographs are included for typical fracture surfaces whose origins of failure were due to grinding cracks, quench cracks, hydrogen flakes, hydrogen embrittlement, flow-through, cold shuts, seams, inclusions, and porosity. This article will be both an interesting and useful first reference for the beginning failure analyst. See also the related paper by Scott which is reviewed in this issue of RATR.

R70-14901 ASQC 844
HOW ELECTRON FRACTOGRAPHY WORKS IN PRACTICE
James A. Scott (McDonnell Douglas Corp., Aircraft Div., Long Beach, Calif.) *Metal Progress*, vol. 95, no. 5 May 1969 p 84–85
(A69-28182)

Description of the practical use of electron fractography in failure analysis. Several cases of failed machine parts are described for the diagnosis of which electron fractography was used. These diagnoses are illustrated by electron fractographs on which the failure causes are shown. Author

Review: This is a very short technical note. Five case histories, with typical fractographs, are cited to demonstrate the use of electron fractography for service failure analysis. Failure analysis, and the consequent feeding back of the results to design-production groups, is an essential technique for achieving high reliability. The article is directed toward the beginner or the uninformed, for whom it will be interesting and of value. The seasoned failure analyst may find it helpful to glance at it. See also the related paper by Phillips and Kerlins which is reviewed in this issue of RATR.

85 DEMONSTRATION/MEASUREMENT

R70-14863 ASQC 851
CHALLENGES OF RELIABILITY TESTING
Robert H. Fuenfhausen (Dayton T. Brown, Inc., Bohemia, N.Y.) *In: Proceedings of the 1969 Product Assurance Conference and Technical Exhibit, Long Island, June 6–7, 1969* Conference sponsored by the American Society for Quality Control, and the Institute of Electrical and Electronic Engineers New York IEEE, Inc. p 97–101 5 refs

The fundamentals of reliability are discussed in terms of the relationship between component reliability and system reliability, and the application of reliability analysis and reliability testing during the design and production phases of a new product. Reliability analysis is considered of particular value during feasibility studies, evaluations of new designs, and modifications to an existing product. Reliability tests, for assessing the system's tendency to fail and the effects of failure, are categorized as development and demonstration, qualification and acceptance, and operational. Factors to implement reliability testing are cited, and test facility requirements are listed. The selection of an environmental laboratory is discussed, and a laboratory evaluation checklist is included. M.G.J.

Review: This paper is less extensive than the title implies. Discussion on "fundamentals of reliability" consists of an oversimplified statement of the relationship between component reliability and system reliability, followed by several points which will

be self-evident to those with experience in reliability testing. There is a brief description of the requirements for a successful environmental laboratory and a checklist for use in selecting an independent laboratory. This paper will convey useful information only to the newcomer to the field of reliability, and even he will find little more than a few basic ideas.

87 MAINTAINABILITY

R70-14864 ASQC 870
THE ART OF MAINTAINABILITY
Siegfried Goldstein (Cutler-Hammer, Inc., Airborne Instruments Lab., Deer Park, N.Y.) *In: Proceedings of the 1969 Product Assurance Conference and Technical Exhibit, Long Island, June 6–7, 1969* Conference sponsored by the American Society for Quality Control, and the Institute of Electrical and Electronic Engineers New York IEEE, Inc. p 102–107

An intuitive approach to maintainability is recommended for the engineer during the early planning of a design. This so-called art requires the engineer to be aware of the physical sciences and mathematics as tools and as constantly expanding resources for his selection and use; his success will depend on how skillfully he selects the proper resources from his stored knowledge and experience. Means of acquiring this intuitive sense are discussed. Several examples of the results of applying this art to real situations in avionics equipment are presented. M.G.J.

Review: As the title implies, this paper develops the theme that maintainability is more of an art than a science. The author's premise is that very often neither time nor knowledge of a proposed new design are adequate to permit a truly scientific approach involving cycles of prediction and design re-evaluation; therefore the design engineer must rely on intuition in arriving at a design with adequate maintenance features. The intuition to which the author refers involves the designer's awareness of the physical sciences and mathematics, and his ability to select the proper resources from his stored knowledge and experience. The paper contains some very worthwhile suggestions for ease of maintenance, including quick fasteners; sliding, twisting, or hinged covers; functional packaging; useful test points; easy access; and simplicity. An example illustrating these features is given. While the author indicates that he is most familiar with electronic systems, he does make reference to ease of maintenance of mechanical systems. Reading of this paper will be well worth the time of design engineers involved with spacecraft for long-duration space missions, in which maintainability will be an important factor.

R70-14865 ASQC 873
DEVELOPMENT OF MAINTAINABILITY TECHNOLOGY FOR SPACE VEHICLES
Barnett Frumkin (Grumman Aircraft Engineering Corp., Space Advanced Systems, Bethpage, N.Y.) *In: Proceedings of the 1969 Product Assurance Conference and Technical Exhibit, Long Island, June 6–7, 1969* Conference sponsored by the American Society for Quality Control, and the Institute of Electrical and Electronic Engineers New York IEEE, Inc. p 151–157 6 refs

An overview is presented of the studies being made to design maintainable systems for manned space vehicles. These include the determination of optimum levels of maintenance, the design of equipment and systems with maximum commonality of parts, the development of techniques for isolating and repairing fluid and electrical systems, and the evaluation of methods for the crew's technical data storage and retrieval. Also discussed is the design of a totally maintainable life support system for installation in a simulated space station environment. Author

Review: As the author points out, in-flight maintenance can be effective in providing a high probability of success for spacecraft missions of long duration. Just as reliability was important in early spacecraft which were not reusable, maintainability is becoming the important factor in the design of systems for manned space vehicles. This is not to ignore the fact that reliability and maintainability are related considerations, but rather to emphasize the need for designers to think in terms of the capability of restoring malfunctioning equipment to operation during flight. This paper describes a program the purpose of which was to investigate the factors involved in designing for maintainability, and to test and evaluate solutions through mock-ups and simulators. This paper will be worthwhile reading for design engineers who wish to get an introduction to maintainability. Good maintainability will make a vital contribution to successful long-duration manned space missions. Much work remains to be done in this field.

88 AVAILABILITY

R70-14881 ASQC 882; 838
LONG-RUN AVAILABILITY OF PARALLELED SYSTEMS
R. Natarajan (Ministry of Defence, New Delhi, India) *Metrika*, vol. 13 1968 p 104–122 10 refs

An analysis of a system with N sub 1 components of one type and N sub 2 components of another type in parallel with uninterrupted running times of each component following exponential distribution and the repair time following arbitrary distribution is presented. The head of the line and preemptive resume priority disciplines have been imposed on the repair of the components. The busy period process is investigated first using the supplementary variable method. Then the general time dependent process in which busy periods alternate with idle periods has been studied in terms of the busy period probabilities and probability of finding the repair facility idle at time t. Finally, the long-run availability of the system in terms of the steady state probabilities for the two cases of priority disciplines has been obtained. Author

Review: The problem treated in this paper is a generalization of the one considered by Gaver in 1963 (see R64-11112). The extension takes the form of introducing a priority discipline in the repairing of the components. This means that instead of having to wait its turn for repair, a given component can pre-empt another one which is already under repair. The system and basic assumptions are otherwise the same as in the case considered by Gaver. The author considers the long-run availability of the system, i.e., the average fraction of the time during which the system is able to perform its function. This is a mathematical paper which will be of interest to other theorists concerned with modelling the availability of systems involving redundancy. Appropriate references to related work are cited. The mathematics was not checked in detail by the reviewer, but a spot check indicates that it is competent.

SUBJECT INDEX

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS VOLUME 10 NUMBER 2

Typical Subject Index Listing

PROBABILITY
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TR-3 c84 R70-12733

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The Notation of Content, rather than the title, is used to provide a more exact description of the subject matter. The category number and *RATR* accession number are used to locate the abstract-review appearing in the abstract section of *RATR*.

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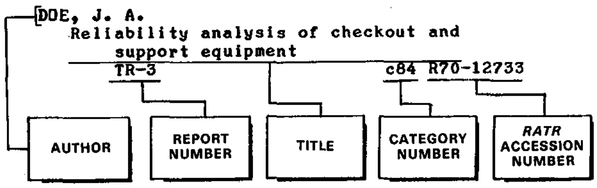
PERSONAL AUTHOR INDEX

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS VOLUME 10. NUMBER 2

Typical Personal Author Index Listing



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Reliability Abstracts and Technical Reviews

MARCH 1970

Volume 10
Number 3

R70-14902—R70-14961

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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EXAMPLES OF CITATIONS IN *RATR*

***RATR* ACCESSION NUMBER**	R70-12733 ASQC 844; 413	**ASQC CODES**
	General Equipment Company, Banville, Calif.	**CORPORATE SOURCE**
TITLE	**RELIABILITY ANALYSIS OF CHECKOUT AND SUPPORT EQUIPMENT**	
AUTHOR	John A. Doe 23 Sep. 1969 27 p refs	**PUBLICATION DATE**
CONTRACT OR GRANT	(Contract NAS15-13411)	***TAB* AND *STAR* ACCESSION NUMBERS**
REPORT NUMBER	(AD-629305; N69-15098; TR-3) Avail: CFSTI	**SALES AGENCY AND PRICE**

***RATR* ACCESSION NUMBER**	R70-12739 ASQC 814	**ASQC CODE**
TITLE	**SEMICONDUCTOR RELIABILITY**	
	Joseph A. Smith (Eastern University, Arlington, Penn.)	**AUTHOR AND AFFILIATION**
JOURNAL REFERENCE	*Electric Journal*, vol. 8, Apr. 1969, p 478–492.	
	(A69-12569)	***IAA* ACCESSION NUMBER**

***RATR* ACCESSION NUMBER**	R70-12765 ASQC 773; 221; 823	**ASQC CODES**
TITLE	**TESTS OF SYSTEMS WITH SOME DEPENDENT FAILURES**	
	Joseph A. Smith (Eastern University, Arlington, Penn.) and B. James White (General Equipment Company, Banville, Calif.)	**AUTHORS AND AFFILIATIONS**
CONFERENCE OR SYMPOSIUM REFERENCE	*Association of Reliability Engineering, Failure Rate Conference, Olney, Tex., Mar. 13–17, 1969, 8 p.* Available from Assoc. of Reliability Eng., New York: $1.00	**AVAILABILITY AND PRICE**
***IAA* ACCESSION NUMBER**	(A69-12407)	

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Reliability Abstracts and Technical Reviews

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March 1970

81 MANAGEMENT OF RELIABILITY FUNCTION

R70-14936 ASQC 815; 844

Battelle Memorial Inst., Columbus, Ohio. Columbus Labs.

MIL-HDBK-5 GUIDELINES FOR THE PRESENTATION OF DATA

D. P. Moon and W. S. Hyler Wright-Patterson AFB, Ohio AFAPL Feb. 1967 252 p refs

(Contract AF-33(657)-10076)

(AD-806651; AFML-TR-66-386)

An attempt is made to present, in a single volume, the procedures that have been adopted. In some instances, these procedures have been fairly well documented, either in attachments to the minutes of past MIL-HDBK-5 meetings, in statistical texts and workbooks, in company reports, or in other available publications. In other instances, it has been necessary to write procedures to cover what has been done in the past. In all cases, an effort has been made to reflect the best analytical techniques and the high assurance requirements established and maintained by the MIL-HSBK-5 coordination group. Author

Review: This is generally a good report. It is a worthwhile addition to MIL-HDBK-5. (The distribution limitation has only recently been removed on this report. It is a pleasure to welcome it to the open literature.) Users of MIL-HDBK-5 should be familiar with this report because some of them tend to misuse the handbook, largely by relying too much on the assumption of *normality* especially in the far tails of the distribution. These authors have in the past written good discussions about MIL-HDBK-5: they have a very balanced attitude toward these data and do not try to extract more out of curves in the handbook than is justified by the method of generation of those curves. There are some statistical considerations about the report that are worth reviewing. The following are examples. 1. The determination of *normality* involving goodness-of-fit tests is one about which applied statisticians have differing opinions. There is least controversy about the fact that just because a distribution has been observed to be reasonably *normal* between, say, 1% and 99%, does not mean that it is *normal* further out on the tails. 2. Another point on which statisticians would probably not differ much is that one must be careful that the sample which was used to estimate the population did in fact represent the subpopulation from which your own material is another random sample. This restriction is often not fulfilled. 3. The utility of tests for goodness-of-fit is controversial. Where the chi-square test is used and the number of degrees of freedom tends to be rather small, a distribution has to be quite oddball before it is rejected. The authors make no reference to the Kolmogorov-Smirnov test which, for data plotted on *normal* probability paper, is often a worthwhile one to use since it is so very simple. Unfortunately, in these tests for goodness-of-fit, if there are a great many data, almost any hypothesis will be rejected, and if there are a very few data, almost any hypothesis will be accepted. The authors do discuss briefly the engineering utility of a distribution but do not quantify it in any way. That is really the important point—is the distribution *normal* enough for engineering purposes (and what are those engineering purposes)? 4. In a chi-square test for goodness-of-fit, many statisticians subtract two additional degrees of freedom for having determined the mean and variance from the data. (The authors subtract no additional degrees of freedom, but mention that some statisticians subtract one). 5. In Section 3.1.6.2, one could also use a least squares analysis to find the value of C. In a primate communication, the first author has commented as follows. "...It may be of interest to your readers to comment that AFML-TR-66-386 was an initial attempt to package and evaluate the many data-handling procedures that have evolved over the years in the MIL-HDBK-5 activity. Since the publication of this report a number of changes and additions to these procedures have been approved by the MIL-HDBK-5 Coordination Group. In order to keep the "Guidelines" current, it is planned to rewrite the contents of AFML-TR-66-386 and reissue them as an integral part of MIL-HDBK-5, which is revised at frequent intervals. The revision of MIL-HDBK-5, including the "Guidelines", is now in progress and publication is planned for late 1970."

R70-14944 ASQC 810; 720

MICROELECTRONIC PROCESS/QUALITY CONTROLS

W. B. Rossnagel (General Electric Co., Re-Entry Systems Dept., Philadelphia, Pa.) *In: Proceedings of the Eighth Reliability and Maintainability Conference, Denver, July 7–9* Conference sponsored by the American Institute of Aeronautics and Astronautics, Society of Automotive Engineers, and the American Society of Mechanical Engineers New York Gordon and Breach Science Publishers 1969 p 199–210 13 refs

(A69-36020)

Discussion of recommendations for the process/quality controls needed in the manufacture, inspection, and test of today's military and space microelectronics and integrated circuits. More than 250 detail points are presented in check-list form for review and application as needed to meet the requirements of these product lines. The microelectronic processes are illustrated in flow charts. Matching check lists are provided for such operations as conductor

screening, resistor abraiding, and discrete part attachment. Several examples of visual-aid accept/reject criteria are included to justify this essential function. I.A.A.

Review: The bulk of this paper is a lengthy series of questions which the author describes as a checklist for microelectronics quality control. The length of this list is impressive, and the details being examined convince the reader of the author's familiarity with the subject. Some of the questions seem to imply an answer which one ought to give, but that proper answer is not specifically stated. Many of the questions are of the nature "have you considered this ...?" as is common in checklists. A checklist of questions is extremely useful, even to experienced people, because it helps assure the proper attention to detail. (The first kind of question is annoying to some people, and they prefer to have a list, say, for example, "Maximum flatness (camber) should be less than 0.4%," rather than asking if it is. This is especially true for those who are trying to use a checklist for tutorial purposes.) Most of the questions (the total list numbers 250-300) require only a simple acknowledgement that a specific precaution has been taken; so the questions do constitute a checklist for the initiated. The subject range is largely limited to thick-film circuits rather than "Microelectronic and Integrated Circuits," as specified in the author's abstract. The paper provides only very limited justification or recommendations (contrary to the promise in the abstract) other than in a general philosophical context; the justification for specific questions in the checklist is not given. If the paper were simply the checklist and its introduction, one could appreciate it more easily for the important document which it is. But the abstract and introduction lead one to expect much more—and it is not there.

R70-14947 ASQC 814

RELIABILITY INFLUENCE ON LIFE CYCLE COSTS

Gerald B. Cohen (Sylvania Electronic Systems, Reliability Assurance Dept., Buffalo, N.Y.) *In: Proceedings of the Eighth Reliability and Maintainability Conference, Denver, July 7–9, 1969* Conference sponsored by the American Institute of Aeronautics and Astronautics, Society of Automotive Engineers, and the American Society of Mechanical Engineers New York Gordon and Breach Science Publishers 1969 p 452–459 10 refs
(A69-25848)

Demonstration that an improvement in reliability of a high-volume piece of military equipment will significantly decrease the total cost of ownership. The principles employed are readily adaptable to commercial equipment where maintenance can be extremely expensive. A case study is created based on a theoretical piece of electronic equipment. Methods for improving reliability are discussed, including screening and burning-in of parts, design review, failure analysis, worst-case analysis, and failure-mode analysis. Pros and cons of redesign, once a project reaches the production phase, are also examined. Projections for future application are outlined. I.A.A.

Review: In the abstract, the author lays out a very ambitious schedule for the paper. The schedule is accomplished by presenting some rough-and-ready calculations and suggestions. Obviously, in only a few pages, no great amount of detail is possible. The approach is largely a very pragmatic one without quibbling about any details along the way. The suggestions are all helpful although obviously one could deviate from them a great deal and still have a successful program. The gross beginner will undoubtedly be confused by the terseness, but a person with some industrial experience can profit from the paper. It would be easy enough to argue with some of the nomenclature, but as long as the user does not push it too far he will not get into any trouble. It is not clear in the example of a reliability-acceptance-test whether this is a sequential test. In a private communication the author has stated that it is indeed a sequential test. However, the calculations are not based on a proper sequential-test procedure. They allow the equipment tester an 80% chance of continuing to test when he should claim that reliability standards are met. The calculations are based on the author's Reference 10, which was covered by R63-10679. That review admonished the reader under no circumstances to use the table or graph in that paper for the design of sequential tests; and this is precisely what the author has done. This part of the paper should be disregarded since it is incorrect. Although there are many good papers dealing with statistical life test acceptance procedures, an excellent one is [1]. It treats sequential and non-sequential methods, presenting useful tables and worked examples. The reader interested in truncated sequential life tests for the exponential distribution should see also the paper by Aroian covered by R65-11854. The paper covers a great amount of material in a very short space. It will not be as easily digested by the reader anxious to learn from it as one might hope from its length.

Reference: [1] Epstein, Benjamin, "Statistical Life Test Acceptance Procedures," Technometrics, vol. 2, November 1960, pp. 435-446.

R70-14949 ASQC 813

THE REAL WORLD OF SYSTEM EFFECTIVENESS

James A. Harkins (Center for Naval Analyses, Arlington, Va.) *In: Proceedings of the Eighth Reliability and Maintainability Conference, Denver, July 7–9 1969* Conference sponsored by the American Institute of Aeronautics and Astronautics, Society of Automotive Engineers, and the American Society of Mechanical Engineers New York Gordon and Breach Science Publishers 1969 p 543–557 28 refs
(A69-36044)

Consideration of studies which indicate that, in the face of increasing complexity, some systems have decreased in relative effectiveness. It is suggested that this may be because program characteristics which are key indices of effective managerial performance are antithetical to the easy achievement of a reliable and maintainable system; because the beliefs, backgrounds, and interests of decisive program personnel alienate them from the system effectiveness disciplines; because the current weapon acquisition process contains numerous artificialities which impede the acquisition of effective systems; and because the activities, relationships, and organization of the system effectiveness disciplines ignore previously cited realities. The people, organizations, value systems, and criteria for accomplishment prevalent in a typical development program are examined. I.A.A.

Review: This is a good paper. Its only drawback is its length, but it is relatively easy to read. When one sees a title such as this containing the phrase *the real world* one is tempted to wonder what the unreal world is like. Unfortunately, the unreal world seems to be the vast majority of papers dealing with program management in which many things are presumed to happen merely because there is an executive directive or contractual requirement to that effect. It seems that the systems effectiveness people have been so busy including more and more hardware activities in their discipline that they have failed to include techniques for making their own activities really effective. The author should be encouraged to submit a shorter version of his paper to some of the trade magazines, which are read much more widely than these annals, and then every time one runs across a paper which shows how wonderfully something is managed, he can pull out the condensation of this paper and estimate just how much that management article had been bowdlerized (sanitized). Unfortunately, most of the papers which

get published and deal with program management must show what a glorious success it all was. Otherwise, management will not allow it to be published. Therefore, there tends to be a wide discrepancy between what we all proclaim loudly we believe in and what actually happens. In a private communication, the author has clarified his intentions to some extent (and his points are good ones) by expressing the thoughts which follow. The paper was not meant to be an exposé of discreditable performance, although it was meant to expose the self-delusion that seems to pervade much of the system effectiveness community. Indeed, it was the very distinction between exposure and exposé that I had hoped to make. If a program is managed in a manner contrary to what system effectiveness people think is correct, it is not because the decisive people in the program are wrong-headed or stupid or fools. Rather, it is a natural consequence of the people, the value systems, etc. . . . The majority of factors that influence a program are adverse if not antithetical to system effectiveness.

R70-14951 ASQC 810; 821

TRANSMISSION PLANNING USING A RELIABILITY CRITERION PART 1—A RELIABILITY CRITERION

Roy Billinton and Murty P. Bhavaraju (Univ. of Saskatchewan, Power System Research Group, Saskatchewan, Canada) *(IEEE Winter Power Meeting, New York, Jan. 26–31, 1969) IEEE Transactions on Power Apparatus and Systems,* vol. Pas-89, no.1 Jan. 1970 p 28–34 7 refs

The utilization of a quantitative reliability criterion in long range transmission planning is proposed. The application of a conditional probability approach to the determination of load point reliability indices in practical systems is discussed and illustrated by a simple hypothetical system study. Failure at a bus is defined by three planning criteria and the reliability level obtained in terms of a probability and an expected frequency of bus failure. The method requires ac load flow analysis at several load levels under possible system component outages. The technique is quite general, and any known operating conditions can be included. Planning based on acceptable load bus reliability levels results in optimum utilization of the investment placed in transmission facilities. Author

Review: Electric power systems are large and complex and therefore their reliability planning has elements similar to that involved in aerospace reliability. The advantage that an electric utility enjoys is that the failure probabilities are much more accurately known than they are in aerospace systems since in the former, radical changes are seldom rapidly made. The constant hazard rate assumption appears to be made, and, interestingly enough, most of the failures can be considered statistically independent even though an outsider would be tempted to think that many of the failures would have common causes. Apparently this is not so. The system is apparently solved by a sort of Monte Carlo process or, if not, the numerical sums and integrations involved are carried out in reasonably coarse steps in order to save computer time. The determination of success-failure cannot be handled easily by the ordinary Boolean logic diagram since most of the success-failure is not the presence or absence of the voltage but whether or not the voltage has gone too low. Therefore, the system operating equations must be solved for each one of the failure conditions. Most of the computer operating time appears to be consumed in solving these system equations rather than in the combination of the probabilities, per se. This paper is concerned with the mathematical aspects of reliability rather than with the hardware and administrative aspects. The language is somewhat different from that used in aerospace reliability calculations. Regardless of these differences, it is most desirable that each group be aware of what the other is doing in order to take advantage of any better techniques that are being developed.

R70-14955 ASQC 813; 851

Frankford Arsenal, Philadelphia, Pa. Quality Assurance Directorate.

PROGRAM STATUS OF ENVIRONMENTAL CRITERIA AND SIMULATION METHODS RESEARCH

Maurice H. Simpson and David Askin Dec. 1968 71 p refs (N69-28477; AD-684353; R-1901) Avail: CFSTI

The report presents the current status of Environmental Criteria and Simulation Methods Research Program. DA Project 1V025001 A622, Program Element 6.21.50.01.1. Period covered is from the inception of the program (FY 60) to FY 67, inclusive. Included is a short discussion of the research plan, a narrative description of accomplishments, and a discussion and evaluation of performance, breakthroughs, and progress. A complete bibliography of published scientific and technical reports, papers, and journal articles related to the program is also provided. Author (TAB)

Review: This report is a very enthusiastic account of the research done over a period of about eight years. The word "breakthrough" in describing the results of the research occurs frequently. An example of such a breakthrough is the fact that equipment should be tested under combined environments rather than sequentially or one at a time. No mention is made of the relative costs of traditional tests versus the suggested new ones or whether the equipment to perform them is available. Reliability engineers ought to read this report so that they can get the picture these authors have of the state of environmental testing before they started their research and the current state of the art. Readers may wish to see the review of another paper by these authors on one phase of this work. It is covered by R69-14445.

R70-14960 ASQC 810

European Space Research and Technology Centre, Noordwijk (Netherlands).

PROCEEDINGS OF THE SIXTH ESRO SUMMER SCHOOL ON ENVIRONMENTS AND THEIR ROLE IN SPACECRAFT TECHNOLOGY. VOLUME 5: SATELLITE RELIABILITY [LES CONDITIONS D'AMBIANCE ET LEURS INCIDENCES DANS LA TECHNOLOGIE DES VEHICULES SPATIAUX. VOL. 5: FIABILITE DES SATELLITES]

M. J. Downey Paris ESRO Jan. 1969 42 p refs Conf. held at Noordwijk, Netherlands, Aug.–Sep. 1968
(N69-24273; ESRO-SP-44) Avail: CFSTI

This document is one of a series of publications (SP-40 to SP-51) covering the lectures given at the sixth ESRO Summer School held in Noordwijk (Netherlands) in 1968. The present lecture constitutes an introduction to the many work areas associated with a Satellite Reliability Programme. A brief description is given of such activities as satellite reliability prediction, failure mode analysis, parts and materials programme, satellite reliability evaluation, etc. Quality assurance is discussed in a similar manner so that a comprehensive picture is gained of the effort necessary to ensure the success of a satellite mission. ESRO

Review: This is a good general introduction to the reliability discipline, whether one is concerned with satellites, other aerospace vehicles, or hardware in general. There is a welcome emphasis on the non-statistical phases of the reliability effort such as design-review and management. The paper is not long; it is easy to read and contains little technical jargon, so that those who are new to the field can readily assimilate it. One will get few, if any, misconceptions from the material (an advantage all too often missing from

general elementary papers). The discussion of statistics is the usual elementary kind and presumes statistical independence of events (unfortunately without explicitly stating so).

82 MATHEMATICAL THEORY OF RELIABILITY

R70-14902 ASQC 824; 612
Picatinny Arsenal, Dover, N.J. Data Processing Systems Office.
RELY–A PROGRAM FOR ESTIMATING OVERALL SYSTEM RELIABILITY BASED ON COMPONENT, SYSTEM, AND FLIGHT DATA
Thomas A. Neff Mar. 1969 48 p
(AD-684927; TM-1891)

A program for estimating overall system reliability by judiciously combining individual component data, laboratory test data and finally flight data as gathered at two different periods in time is presented. All data used in arriving at this single reliability estimate is assumed to be attribute in nature. Author

Review: This is a sufficiently detailed description of the RELY computer program to enable the reliability analyst to understand and use it, provided he has some prior knowledge of programming. The underlying basis for the methodology is not described, but a reference is cited in which this may be found. A significant assumption is that the true probability of a component functioning has a beta distribution. Data from an early point of time is "degraded" relative to data obtained later by a factor corresponding to the area common to the two pertinent beta distributions. A necessary input is, of course, the probability equation for the circuit or system being evaluated. The paper is a clear description of the program and its operation, accompanied by a simple example. Those who wish to know more about the background for it will need to obtain the reference which the author cites.

R70-14914 ASQC 824; 844
Department of Supply, Melbourne (Australia) Aeronautical Research Labs.
A TWO-PHASE DAMAGE THEORY FOR LIFE DISTRIBUTION PREDICTION
M. J. O'Neill Oct. 1968 31 p refs
(N69-29754; ARL/SM-322) Avail: CFSTI

A two-phase damage accumulation hypothesis is proposed to explain some features of the results obtained in rotating bending tests on a high strength aluminum alloy. The results of life calculations using this hypothesis are presented and compared with the observed lives and with Miner rule predictions for a number of step tests and one program test. The two-phase rule appears generally superior to the Miner rule but at some expense in computation and with the added complexity of requiring cycles in each phase rather than total cycles to failure at each stress condition. Some of the tests show a coaxing effect, a phenomenon which is not predicted by the damage hypothesis in its present form. Author

Review: The theory of cumulative damage for metals in fatigue continues to attract the attention of theorists and experimentalists alike. Virtually all of the newer theories compete with the linear theory of cumulative damage (Miner's Rule) because that rule is so simple to apply. Many of the theories of cumulative damage which have been proposed do not take into account the scatter in fatigue life which is usually observed. The theory proposed in this paper does take scatter into account, but, in so doing, is forced to make additional assumptions. The assumption that a group of specimens would maintain their relative ranking of life regardless of the stress level at which they were tested is an appealing one (it improves the tractability), but it is also one which is extremely difficult to verify. It is easy to find specific cases in which the median values of fatigue life for two different materials or two different processes will actually cross, so that the order of ranking is reversed at high and low stresses. (The above discussion illustrates the dilemma of the author in trying to make an appropriate assumption.) The author appears to evaluate his theory quite honestly in that not all the experiments show that it is a better theory than the linear one. He does point out the appealing nature of his main assumption (damage rate changes at some point in specimen life); it is at least analogous to crack initiation and crack propagation stages often mentioned in the physical basis of fatigue. This paper is much more suited to the experimenter in fatigue whether he is working with machines or pencil-and-paper, rather than being useful for designers. The author does not claim to have discovered a new law of nature; he merely puts forward his theory as being an interesting hypothesis and shows how it holds up under limited experimental testing. Viewed in that light, it is a good contribution to the literature.

R70-14915 ASQC 824; 830
Air Force Systems Command, Wright-Patterson AFB, Ohio. Foreign Technology Div.
AUTOMATIC DETECTION OF MALFUNCTIONS IN ELECTRONIC DIGITAL MACHINES
L. A. Korytnaya July 1967 20 p refs Transl. into ENGLISH from Russian publ.
(Contract AF33(657)-16408)
(AD-689260; FTD-HT-23-599-67)

A theoretical investigation of the design principles of devices for the automatic detection of failures in digital program automatons is presented. The description and analysis of the operation of real elements, in which failures lead to a disruption of the operation of units of the digital program automaton, are given in terms of a formal description of ideal elements. The following units of a digital program automaton are analyzed in detail: Memory device (subject G1), arithmetic unit (subset G2); control unit (subset G3), information input and output units (subsets G4 and G5), and the unit for coupling with the controlled plant (G6). The basic principles for the design of logic circuits are examined. In checking the working order of a logic circuit of any complexity by means of the control automaton A, the problem of constructing the control program may be reduced to the execution of the following operations: (1) the construction of an abstract automaton Ac which describes the logic circuit G; (2) an analysis of Ac equivalent to the prescribed logic circuit G; and (3) a check of the proper operation of Ac by means of universal control operations. Author

Review: This paper (from its title) sounds very pertinent to the work of design and reliability engineers and is only recently available through CFSTI. Unfortunately, it is of interest only to the theorist working with the description of computers in terms of automata. Virtually all of the paper is taken up with translating the general behavior of the computer into language appropriate for automata. A few restrictions on the detection system are given, but otherwise the paper is of no concern to designers or reliability engineers.

R70-14928 ASCQ 824; 412

Stanford Univ., Calif. Statistics Dept.

AN EXACT LOWER CONFIDENCE BOUND FOR THE RELIABILITY OF A SERIES SYSTEM WHERE EACH COMPONENT HAS AN EXPONENTIAL TIME TO FAILURE DISTRIBUTION

Tapas K. Sarkar Mar. 1969 30 p refs
(Contract NONR-225-(53))
(AD-684860; TR-117)

A complex system consisting of several components in series is considered. The system as a whole is either impossible or too expensive to test. The only data available are the times to failure of the components when tested individually. Based on these data an exact lower confidence bound for the reliability of the system is obtained. Initially, the method is developed for the case when the components are independent. Later the method has been extended to the case when the components are dependent and have multivariate exponential time to failure distribution. The sampling method considered is type II censoring of r out of n with or without replacement. An asymptotically smallest confidence interval has also been developed. Author

Review: This paper is addressed to a problem which has attracted a great deal of attention by reliability theorists, namely, that of setting confidence intervals on system reliability on the basis of component test data. The basis for the method proposed in this paper is the well-known relationship between the sum of independent exponential variables and the chi-square distribution, due originally to Epstein. The method is illustrated for the case of two components. Extensions discussed in the paper include (a) when the number of components is greater than 2, (b) when the number of components is 2 and the distributions are not independent, (c) when the distributions are not independent and the number of components is greater than 2, (d) for the case of type II censoring of r out of n with replacement. An asymptotically smallest confidence interval based on maximum likelihood estimation is developed for the case of two components. Comparisons are made with certain other methods which have been proposed and for which the references are cited in the paper. This is a mathematical paper which will be of interest to the theorist rather than to the reliability engineer.

R70-14929 ASQC 824

THE SAMPLING DISTRIBUTION OF AN ESTIMATOR ARISING IN CONNECTION WITH THE TRUNCATED EXPONENTIAL DISTRIBUTION

Jan M. Hoem (Univ. of Oslo, Oslo, Norway) *The Annals of Mathematical Statistics,* vol. 40, no. 2 1969 p 702–703 5 refs

Expressions are derived for the independent exponentially distributed random variables and for the corresponding order statistics. A theorem for the sampling distribution is postulated. M.G.J.

Review: Time-censored data are of frequent occurrence in life-testing situations; thus, the sampling distribution which is obtained in this brief mathematical note is of practical importance. The development is clear and concise, and relevant references are cited. While the discussion in the paper will be of interest only to the theorist, the result will be of value to the practical reliability analyst. Non-statisticians should note carefully that the model distribution of lives is not truncated; rather it is the testing times which are censored. The title does not make this clear.

R70-14930 ASQC 824; 413; 822

A TEST FOR THE HYPOTHESIS THAT TWO EXTREME-VALUE SCALE PARAMETERS ARE EQUAL

Nancy R. Mann (Rocketdyne, Canoga Park, Calif.) *Naval Research Logistics Quarterly,* vol. 16, no. 2 June 1969 p 207–216 8 refs
(Contract AF33(615)-2818)

A statistic is determined for testing the hypothesis of equality for scale parameters from two populations, each of which has the first asymptotic distribution of smallest (extreme) values. The probability distribution is derived for this statistic, and critical values are determined and given in tabular form for a one-sided or two-sided alternative, for censored samples of size $n1$ and $n2$, $n1$ = 2, 3, . . ., 6, $n2$ = 2, 3, . . ., 6. The power function of the test for certain alternatives is also calculated and listed in each case considered. Author

Review: The first extreme-value distribution of smallest values is the distribution of the natural logarithms of failure times having the two-parameter Weibull distribution. Thus the test discussed in this paper is essentially a test for the equivalence of two Weibull shape parameters. This paper is therefore relevant to reliability analysis because of the fairly common use of the Weibull distribution in the interpretation of life-test data. It is written for the statistician rather than the engineer, as it is concerned with derivation of the test statistic, its probability distribution, the critical values which are tabulated in the paper, and the power function for selected alternatives. The relationship to previously published work is clearly indicated, and eight references are cited. Of these, items 4, 5, 6, and 8 were covered respectively by R68-14099, R68-13758, R69-14371, and R69-14372.

R70-14931 ASQC 824; 552; 822

New York Univ., N.Y. Industrial Engineering Dept.

GAMMA AND WEIBULL LIFE-QUALITY PLOTS

John H. K. Kao Mar. 1968 27 p refs
(Contract NONR-285(62); DA-31-124-ARO(D)-338)
(AD-690876)

The life quality of an industrial product can be characterized by its lifelength distribution. Given 'good' failure data, the simplest way to estimate the lifelength distribution is by the probability plot. This paper presents two such plots: gamma and Weibull (Form 2) probability plots which represent two theories of failures. The gamma distribution arises from the rope (or parallel-structure) failure model while the Weibull distribution comes from the chain (or series-structured) failure model. In rope model, the item fails when the last or the strongest strand of the rope fails whereas in the chain model, the item fails when the first or the weakest link of the chain fails. Scales which facilitate quick estimates for the mean and standard deviation of the lifelength distribution are also presented along with the plots. Author

Review: This report makes a good contribution to reliability methodology by presenting two graphical methods for the analysis of failure data. The gamma distribution is used with the rope (or parallel-structured) failure model, and the Weibull distribution for the chain (or series-structured) failure model. The report includes an excellent discussion of the basic statistics of these two models, and a description of the corresponding plots. It can be understood readily by anyone with a prior knowledge of fundamental statistics. The concluding remarks should be noted carefully by anyone who wishes to use these graphical methods of estimation. While the paper is self-contained, those who desire more details on graphical methods of estimation in life testing may wish to refer to some of the eight references which are cited by the author.

R70-14933 ASQC 824
System Development Corp., Santa Monica, Calif.
ON CUMULATIVE DAMAGE AND RELIABILITY OF COMPONENTS
V. K. Murthy and B. P. Lientz Wright-Patterson AFB, Ohio AFAPL
Oct. 1968 34 p refs
(Contract F33615-67-C-1865)
(AD-680008; ARL-68-0180)

Let T, X (t), and C denote the time to failure, the accumulated damage by time t, and the 'critical' damage. Let F be the distribution function of T. Let 'E' stand for the event of the component undergoing damage and (t sub n) denote the sequence of intervals of time between successive occurrences of 'E'. Let T sub n = summation over n of t sub i and Y sub i denote the amount of damage experienced at time T sub n. Assume (t sub n, Y sub n) is a sequence of independent, identically distributed variables with distribution function H (t,y), so that (t sub n) and (Y sub n) are renewal processes. The inequality F (t) < or = H (t,infinity) is obtained with equality if and only if C = 0. For 'E', a Poisson process, sufficient conditions are given for F, to be IHR and DMR. The classes of distribution functions are considered with the topology of complete convergence. Empirical estimates for F from observing occurrences of 'E' are given. Author

Review: This is a highly mathematical paper and is yet another contribution to the ever-growing literature on cumulative damage. In contrast to many other papers, this one still presumes a linear theory of cumulative damage: that is, that the amount of damage done at any particular time is additive to the previous damage and is independent of the amount of damage already existing. The remainder of the paper is concerned with some of the time characteristics of this process. Some very appropriate comments are made in the text concerning the exponential distribution and its non-universality. Not all of the detailed mathematics was checked, but it appears to be very competent. The authors have not been concerned with the engineering implications of this research, and it would be worthwhile to extend this paper by considering those implications. It would be interesting to see what processes and parts might be describable by this kind of behavior.

R70-14937 ASQC 824; 844
Central Electricity Generating Board, Berkeley (England). Research and Development Dept.
A METHOD OF ESTIMATING THE SHORT ENDURANCE FATIGUE LIFE OF STRUCTURAL COMPONENTS-PART 1, CRACK INITIATION
K. Jerram Sep. 1967 19 p refs
(RD-B-N924)

A method of estimating the fatigue life of structural components is presented. The life is divided into crack initiation and crack propagation phases. It is shown that crack initiation in a notched testpiece may be predicted from the calculated cyclic strains and crack initiation data from plain fatigue specimens. Author

Review: Fatigue is an extremely important failure mode in mechanical structures. Thus the ability to analyze fatigue behavior is important for the aerospace industry. This paper is a combination of theoretical discussion and experimental results (as is usual in published work, the two agree reasonably well). The author has done a good job of trying to find methods of calculation which are both reasonably tractable and reasonably accurate. At its present stage of development, the theory is still being tested and the paper is therefore of more use to those doing research in fatigue than to designers and reliability engineers. There is no consideration of scatter in the fatigue life. Scatter tends to be much less at short lives than it does at long lives. It is not clear how feasible this method will be in the general case of stress concentration in an oddly shaped part.

R70-14938 ASQC 824; 412
Boeing Scientific Research Labs., Seattle, Wash. Mathematics Research Lab.
APPROXIMATE CONFIDENCE LIMITS FOR COMPLEX SYSTEMS WITH EXPONENTIAL TIME UNTIL FAILURE OF THE COMPONENTS
J. M. Myhre (Claremont Men's Coll., Claremont, Calif.) and Sam C. Saunders Oct. 1968 30 p refs *Its* math. note no. 577
(N69-21865; AD-682117; DI-82-0770) Avail: CFSTI

The asymptotic distribution of the log-likelihood ratio is shown to provide a method of determining approximate confidence limits for any coherent system when each component has an exponential life with unknown failure rate and component performance data are provided in the form, number of failures (minimum of one) and total operating time. Some computational methods to facilitate the determination of the lower confidence bound at a given level are provided in the important case of a series system. A numerical comparison is made between the nominal confidence level and the actual confidence level, by counting the number of times the true reliability is caught within the confidence bound determined by the likelihood ratio method using repeated computations from random numbers generated with a specified distribution. Author (TAB)

Review: This is a highly theoretical paper which treats a problem of continuing interest in reliability. The detailed mathematics was not completely checked, but it appears to be quite competent. An example was used to test the method of studying the bounds and was found to be slightly conservative in that particular case. It would be desirable to put this information in a form which is accessible to designers and reliability engineers and publish it in one of the engineering journals.

R70-14943 ASQC 824; 872
"BAD-AS-OLD" ANALYSIS OF SYSTEM FAILURE DATA
Harold Ascher and Harry Feingold (Naval Applied Science Laboratory, Brooklyn, N.Y.) *In: Proceedings of the Eighth Reliability and Maintainability Conference, Denver, July 7–9, 1969* Conference sponsored by the American Institute of Aeronautics and Astronautics, Society of Automotive Engineers, and the American Society of Mechanical Engineers New York Gordon and Breach Science Publishers 1969 p 42–62 16 refs

Some of the basic probabilistic concepts of repairable system reliability are presented. These principles are clarified by applying them to real data. It is shown that the failures of some submarine diesel engines are not governed by a renewal process and a non-homogeneous Poisson process will be fitted instead. It is shown that the conclusions drawn about the diesel engines are in sharp disagreement with the spurious exponentiality indicated by an earlier analysis based on the a priori assumption of renewal. It is shown that spurious exponentiality is a likely result whenever renewal is assumed rather than statistically established. If renewal is rejected the simplest model consistent with this result is the bad-as-old model and an appropriate bad-as-old model should be selected and tested for goodness-of-fit. Author

Review: This is a worthwhile paper; it presents some good ideas for consideration. The concept of "bad-as-old" is intriguing

and potentially very descriptive of many kinds of hardware. For those who wish a more detailed review, the following discussion is presented. The paper will be reviewed in two parts–a discussion of the general concepts, then the authors' treatment of them. Many of the points, of course, are recognized and discussed by the authors in the paper. The authors' notation is used wherever feasible. 1. (a) The basis of the entire discussion is the nonhomogeneous Poisson process. This is the same as the usual homogeneous one except that the *intensity* (rate of occurrence) of the process is a deterministic function of time as measured from the original time origin. The very important property of this process is that the occurrence of an event in a future time interval is completely independent of the way events have occurred in the past. The probability of occurrence of an event depends only on the value of the *intensity* over that future time interval. The nonhomogeneous process has some of the same formulas and properties as the usual Poisson process wherein the *intensity* is a constant. If the *intensity* of the process is ρ, then $m \equiv \int \rho(t)dt$. The authors call ρ the *peril rate.* Over the time interval of interest, m is the mean number of failures, and the probability of n failures in that interval is given by the usual Poisson formula with m the Poisson parameter. The formula for reliability is (no failures) $R \equiv \exp(-m)$. It can be seen that ρ is analogous to the hazard rate and m is analogous to the cumulative hazard in the usual treatment of nonrepairable equipment. The authors derive/show these formulas in the text. (b) The bad-as-old concept states that the condition of a repairable equipment just after a repair is statistically the same as it was just before the repair. An equivalent way of saying this is the following: Consider a great number of statistically alike equipments running under the same environment and that we are using one of the equipments. *Spares* is the name for all the ones we are not using. Whenever any of the spares fail, it is discarded and is of no more concern (and is no longer called a *spare*). Whenever the one we are using fails, we discard it and select a spare. We continue to use it until it in turn fails; then we select yet another spare. The single equipment which is repaired under the bad-as-old concept has exactly the same behavior as a set of nonrepairable equipments used in the above way. In the equivalent system, a failed equipment is replaced by one which, before the failure occurred, was statistically like the one that failed. This is what we mean by the "bad-as-old" concept. The probability of failure in the next instant (dt) is h(t)dt for any live system, $h(t) \equiv$ hazard rate. For the authors' system, the probability of failure in the next instant (dt) is $\rho(t)dt$, $\rho(t) \equiv$ peril rate. Since the two systems are equivalent, the hazard rate and peril rate are identical functions of time, regardless of how they are initially defined. This point is not obvious; so its importance should not be overlooked. In summary, if one takes a large number of equipments and (1) never repairs them, (2) calculates the hazard rate for that equipment type, then (3) that hazard rate will be the exact same function of time as is the peril rate for any single piece of that equipment when the equipment is maintained (repaired) under the *bad-as-old* policy. Even though h(t) and $\rho(t)$ have a different conceptual basis, each is the same function of time. The bad-as-old concept is a perfectly legitimate model for repair activities in that it contains no logical inconsistencies. As the authors point out, it must be compared with other models proposed for the same purpose to see which gives the best fit. (c) It appears very likely that the hypothesis of a nonhomogeneous Poisson process to describe repair is logically equivalent to the bad-as-old concept of repair. That is, the one is not a special case of the other but either one implies the other. In the special case where the *intensity* is constant, the bad-as-old is exactly the same as good-as-new since then, a system known to be in good condition is also known to be no different statistically from what it was originally. 2. Now, to discuss the authors' treatment of the topic. (a) The authors' discussion of the difference between a repair situation and a discard-at-failure situation is good and helps to clarify some points upon which there is much confusion in the literature. His introduction of the peril rate ($\equiv$ the Poisson *intensity*) is only for the nonhomogeneous Poisson process and is not appropriate for repair processes in general. This is true because $\rho(t)$ is presumed to depend only on the time since the origin and not on any previous failure events. This is not true in general for repair situations. This point is stressed by the authors in their Section IV. (b) There appears to be some confusion (it was not clear to these reviewers, perhaps it is clear to others) about unconditional versus conditional probabilities associated with the hazard rate. The condition implied by the phrase *conditional probability of failure* is that the system is operating at time t–one of the authors' footnotes notwithstanding. It is not good practice to call this an unconditional probability and try to assume implicitly that the important condition is understood. The authors do deal with another condition which is that of a repair's having been effected. Their theory effectively implies that this second condition does not affect the hazard rate. (c) In Section VI, the proof that *bad-as-old* is equivalent to a nonhomogeneous Poisson *(nhP)* process seems circuitious. The reason *bad-as-old* is equivalent to a *nhp* appears to be because the inherent assumptions for the *nhP* process were introduced into the derivation. (d) It is not at all clear why the Weibull distribution with shape parameter greater than 1 is not suitable to describe the bad-as-old concept. Any distribution function which is legitimate for nonrepairable equipment is legitimate (in its hazard rate form) to use as the intensity of a nonhomogeneous Poisson process–as is clear from part 1(b) of this review. The scale parameter can be used to adjust for the fact that not very many components are going to be replaced in the time interval under consideration. The Weibull will be just as useful as a Gaussian process, which surely the authors must be allowing. (e) In Appendix B, the authors use the maximum likelihood (ML) solution for β, one of the parameters in their time-varying Poisson *intensity* ($\log \rho = \alpha + \beta t$). This is a very reasonable thing to do. The thing that is not clear at all is why they went on to get an awkward least squares solution for α (the other parameter in that expression)–spending almost a whole page on it–rather than using the ML solution for α, especially since it has such a simple form, viz., $\exp(\hat{\alpha}) = (\hat{\beta}\Sigma tj + n)(1/T) - \hat{\beta}n$. With these ML solutions, it is also possible to estimate the uncertainty in each of the parameters This uncertainty can also be used in confidence like statements. The equation above is adapted from the authors' reference 5, page 45, equation 4. (f) This paper is somewhat clearer than others the first author has written on this topic (see, for example, R69-14239), but it still requires further extension in order that all of the important properties of bad-as-old will be more apparent. It is the logical implications of the assumptions that need to be explored more fully; so we can understand the concept better. For example, one could try to prove (or disprove) the relationship suggested in 1(c) above that bad-as-old and a nonhomogeneous Poisson process each implies the other. The authors have demonstrated a one-way equivalence, but apparently have not demonstrated the reverse. (g) It is important to remember that a piece of machinery which has been torn down for a specific repair is no longer from the same population as the original equipments whose internal parts were not visible. Thus, an engine torn down to replace a failed seal and which shows virtually worn-out bearings is from a different statistical population than one which is known only to have failed from a bad seal. In the practical situation, one would go ahead and replace the bearings, seeing that they were in bad condition, but this kind of thing would be difficult to take into account in the description of the population and its behavior. (h) Finally, we consider how applicable the bad-as-old model is. It may often be adequate, but a great many papers in the literature suggest that with mechanical equipment it is often not a good model; this is especially true where some of the components, such as bearings, experience severe wear-out. However, as the authors point out, it may be useful for a major portion of a system such as an automobile (minor repairs and upkeep being disregarded for the purpose).

Bad-as-old is not applicable in any event after a sufficient length of time has passed so that the hazard rate of the original equipment is quite high or its rapid increase is dominated by one particular part. The restriction required by the authors is essentially the same as saying that the conditional probability of failure (the condition is that the system has failed) is small for the failed part. Obviously, in any situation where the model can be shown to be adequate, the authors' discussion of the appropriateness of overhauls, etc. is applicable and there would be little point in making any repairs on parts which have not failed or upon which failure is not clearly impending.

R70-14945 ASQC 822
DISTRIBUTIONS OF CYCLES-TO-FAILURE IN SIMPLE FATIGUE AND THE ASSOCIATED RELIABILITIES
Dimitri Kececioglu, Richard E. Smith and Ernest A. Felsted (University of Arizona, Aerospace and Mechanical Engineering Dept., Tucson, Ariz.) *In: Proceedings of the Eighth Reliability and Maintainability Conference, Denver, July 7–9, 1969* Conference sponsored by the American Institute of Aeronautics and Astronautics, Society of Automotive Engineers, and the American Society of Mechanical Engineers New York Gordon and Breach Science Publishers 1969 p 357–374 15 refs
(A69-36032)

Description of a probabilistic approach for analyzing time-dependent failures of components subjected to simple fatigue loading. Experimental data on aluminum and steel wire specimens subjected to such loading are given and analyzed to determine the distributions of cycles to failure at various stress levels. Methods for predicting the reliability of such components are given so that specified reliabilities may be designed into them. Author (I.A.A.)

Review: This is a tutorial paper since the statistical concepts of fatigue have been known for some years and the statistical analysis itself is very standard. It will be useful to those people who wish a well-worked-out tutorial example of the application of statistics to fatigue, and who are sufficiently informed to evaluate the material critically. The basic ideas are correct. Fatigue is a process which almost always must be represented by statistical calculations. The data themselves are useful only as examples of a technique since one would not necessarily expect his own material to have the same behavior. For example, the steel wire is described only as cold drawn with a given tensile and ultimate strength; the modulus for elasticity is obviously a nominal value. The aluminum wire has a somewhat more adequate description, but still incomplete. The biggest difficulties involved with applying this technique are not necessarily that people do not know about it, but that it is not economically feasible to fatigue-test as many specimens as the authors suggest for generating curves of actual parts, and it is very difficult to extrapolate fatigue data from standard fatigue specimens to real parts. Some points to consider carefully when reading the paper are the following. (1) On page 358, the concept of statistical significance is used twice when what is meant is engineering significance. The statistical significance of an experiment can be calculated regardless of the number of specimens. It is usually desired that the number of specimens be sufficient so that the results have engineering significance. Furthermore, statistical significance has nothing to do with whether or not the failure distribution obtained is truly representative of the material. (2) On page 359: "Once the confidence limits have been calculated for the sample mean and standard deviation, it can be stated with the specified confidence level, $(1-\alpha)$, that the true mean and standard deviation will lie between the calculated confidence limits." When giving the mean and standard deviation of a normal distribution within certain confidence limits, it should be remembered that they are two independent statements, not a single confidence statement. (3) On page 359: "... However these parameters [skewness and kurtosis] do not give a percentage probability that the sample data are actually represented by these distributions. . . . To calculate a probability of distribution fit, the Chi-Squared goodness-of-fit test is used . . . ." The authors are correct in stating that kurtosis and skewness do not give a "percentage probability that the sample data are actually represented by these distributions." But of course neither does the chi-square test. They can however be used in exactly the same manner as the chi-square test; that is, one can calculate the probability that one would observe such extreme results if the null hypothesis were true. Thus, the kurtosis and skewness tests do more than the authors claim and the chi-square test does less. (4) The discussion of the chi-square test on page 359 is of a very cookbook nature and suffers from the deficiencies of that kind of presentation. Examples are the following. (a) It is asserted that tests should always be run at a 5% statistical significance level–there is nothing magic about the number 5%. (b) One must be careful about attributing the value zero of a chi-square sum to a perfect fit (as the authors do). One would be very suspicious if he obtained a zero chi-square value since, of course, when the hypothesis is exactly true, the chi-square sum will have the chi-square distribution (this is the basis of the whole test). (5) The discussion on page 367 of variation in the 90% confidence interval around the mean for both the mean and the standard deviation is not at all clear. The 90% confidence interval depends greatly on the number of samples tested; so its variation with stress is as much a reflection on the number of items tested at each stress level as it is on the variance at each stress level. (6) The authors have not considered the Weibull distribution at all, whereas it is one very commonly associated with fatigue lives. (7) In the examples on page 370, the materials are referred to only as steel and aluminum. This could imply to the neophyte that steel and aluminum are sufficient descriptors of a material for determining its fatigue characteristics; this is not the case. Furthermore, there is no mention of stress concentrations which occur in most applications of a shaft (wherever something is fastened to the shaft, there tends to be a stress concentration). (8) On page 371, the authors raise the question of the *confidence* that can be ascribed to these reliability values. If it is statistical confidence, obviously the answer can be calculated. If it is engineering confidence, the answer is "very little." It is not clear in what sense *confidence* is being used. (9) There is a typographical error in formulas 5c and 6c; apparently the symbol χ is left out. (10) There is no discussion of the problem of the fit of the distribution in the central portion of the data *vis a vis* the fit in the tail regions. For reliability, one is often concerned about a relatively small fraction of failures (on the order of a few percent or less) and it is the goodness of fit out in that tail region that is important.

R70-14948 ASQC 824; 433; 851
A DEMONSTRATION BAYESIAN APPROACH TO RELIABILITY DEMONSTRATION
H. Balaban (ARINC Research Corp., Annapolis, Md.) *In: Proceedings of the Eighth Reliability and Maintainability Conference, Denver, July 7–9, 1969* Conference sponsored by the American Institute of Aeronautics and Astronautics, Society of Automotive Engineers, and the American Society of Mechanical Engineers New York Gordon and Breach Science Publishers 1969 p 497–504 7 refs
(A69-36039)

Description of the Bayesian approach to reliability demonstration tests for predetermining any two of three factors–namely, sample size, producer's risk, and consumer's risk. Demonstration tests are developed for equipments that have exponential failure distributions and for equipments for which binomial-type tests are appropriate. I.A.A.

Review: The first part of the paper is tutorial, intended to show engineers the power of the Bayesian approach; the latter part contains new applications. It is a good paper and should be considered seriously. The following comments are based on opinion rather than established fact, since there are many questions in the application of subjective probability which are not yet resolved. In the early part of the paper, the author appears to be using probability in its relative-frequency sense. In the latter part of the paper, while not entirely clear, it appears that probability is being used in a degree-of-belief sense. It helps to keep these two interpretations of probability theory separate in order to avoid confusion on the part of the user. These comments about interpretation of probability are controversial, and there is not a clear-cut unanimity among and between statisticians and engineers on the subject. Both interpretations are legitimate uses of probability theory, but it does help if engineers know what they mean by probability when a number comes out of a formula. It appears that the procedures given in this paper discuss the probability of the parameter for the particular lot under consideration rather than the actual distribution of that parameter for a great many lots. For example, if one knew exactly what the distribution of the parameter for all the lots was, and then performed an extensive test on one particular lot, the apparent distribution of that parameter would change drastically whereas, by hypothesis, the actual distribution of the parameter changed not at all. Thus, it is important to be explicit about what one means by a probability distribution of a parameter even when one is willing to use the classical definition of a parameter as being fixed but unknown in any given instance.

R70-14956 ASQC 824; 423
Sheffield Univ. (England). Dept. of Probability and Statistics.
THE PRODUCT OF INDEPENDENT BINOMIAL PARAMETERS
J. B. Garner Dec. 1968 21 p refs
(RR-53/JBG-4)

The problem of finding confidence intervals for the product of independent binomial parameters is approached from a Bayesian viewpoint. The exact density function is given, simple approximations to the density function are presented, and Bayes factor type tests of significance are considered. The problem of comparing two products is also discussed. Author

Review: Calculating an estimation interval for the product of independent binomial parameters is a problem that has long held the interest of reliability theorists and is one for which several approximations already exist in the literature. This paper provides some good additional discussion on the matter. It uses a Bayesian approach with conjugate prior and then uses various approximations of the resulting distribution. (The mathematics was only spot-checked but appears to be quite competent.) The reliability engineer who is not a statistician is advised to remember that the estimation intervals in this paper are Bayesian intervals, not confidence intervals, and that there is some statistical distinction between the two (although the engineer may not care to concern himself with it).

R70-14959 ASQC 824; 612; 831
United Kingdom Atomic Energy Authority, Risley (England). Authority Health and Safety Branch.
THE CALCULATION OF RELIABILITY OF SYSTEMS THE PROGRAM NOTED
E. R. Woodcock 1968 78 p
(N69-23799; AHSB(S)R-153) Avail: CFSTI

There are many circumstances in which it would be useful to know the probability, as a function of time, that a device or system will perform in the desired manner when called upon to do so and how long it is likely to take to act. The systems can vary in complexity from a simple burglar alarm to a complete automatic protective system for a nuclear reactor, from a small electronic amplifier to a large electrical supply network with a prescribed maintenance schedule, and in numerous other fields. Practically all of these systems may be reduced to a logical flow network which is often of large size. The methods of analysis of logical flow networks are discussed. A versatile computer program that has been developed to deal with networks too large to be tackled by other methods is described. The solution of a sample problem is also described in detail in an appendix. Author (NSA)

Review: This report is concerned with the calculation of the reliability of a system which can be reduced to a Boolean logic diagram. The approach is somewhat different from the usual one in that (1) the success of the system is calculated as a function of time and (2) once an event has happened it can "unhappen" (a failure can be repaired). The procedure is to employ a computer to reduce the system by using known combinations of subsets of elements and thus eventually get a system that is manageable in size. Not all of the mathematics nor the program was checked, but they appear to be competent. Those who are involved with the calculation of reliability of complex systems should be aware of this effort. No indication is given of running time, either in reduction over other methods or in absolute values. (The author in a private communication has indicated that running times vary according to the size of the system and the options requested, but typical times on the IBM 7090 for a system with about 100 elements vary between 15 seconds and 5 minutes a case.) The program is flexible in that it allows for other than exponential failure and repair times.

83 DESIGN

R70-14907 ASQC 830
Air Force Systems Command, Wright-Patterson AFB, Ohio. Foreign Technology Div.
POSSIBILITIES OF ENHANCING THE RELIABILITY OF DISCRETE COMPUTING AND CONTROL DEVICES
V. B. Svechinskiy 29 May 1968 14 p refs Transl. into ENGLISH from tr. Energ. Inst. (Moscow), no. 59, 1965 p 245–252
(N69-17548; AD-679793; FTD-HT-23-56-68) Avail: CFSTI

The problem of constructing a high-reliability automaton reduces to the following: given a structurally complete system of functional elements as well as transition and output tables of a discrete-action automaton, construct a self-correcting discrete-action s-rank automaton from elements of this system. The rank of the automaton is taken as the maximum number of any elements that may malfunction without disturbing the automatons performance. It is shown that an increase in the rank leads to an increase in reliability. The synthesis of an automaton of the rank 1 is examined. TAB

Review: While its title and abstract imply that it would be of interest to those concerned with the design of high-reliability computers, this paper is made less useful by the literal translation form in which it appears. The use of "reservation" to mean "duplication," is an example, as well as the appearance of the word "tack" or "tact," probably to mean "instant of time." The stilted English

makes much rereading necessary. The author is very indefinite as to the method to be used in synthesizing reliable automata, and the single example (which corrects only a single error) is not much help. The remarks on the evaluation of reliability form the more useful part of the paper, although his observation that a machine can be more reliable than its elements is well known, being the subject of von Neumann's paper (author's reference 3). On the whole, this paper does not seem to be worth the not inconsiderable effort expended in reading it.

R70-14913 ASQC 833; 815

HIGH RELIABILITY MAGNETIC COMPONENTS FOR SPACE APPLICATIONS

H. K. Inao, and M. E. Lippman (Hughes Aircraft Co., Research and Development Div., Culver City, Calif.) *In: Proceedings of the 1969 Annual Electronic Components Conference, Apr. 30–May 2, 1969* Conference sponsored by the Electronics Industries Association and the Parts, Materials and Packaging Group of the Institute of Electrical and Electronic Engineers Washington, D.C. McGregor and Werner, Inc. 1969 p 453–457

Details are given on a development and manufacturing program for high reliability magnetic components intended for use in space applications. The program has proved successful based on the results of Surveyor, Syncom, Early Bird, and other space communication satellites. It involves (1) the basic engineering design necessary to attain all functional parameters, followed by (2) general manufacturing method, (3) planning and control requirements, and (4) inspection and testing procedure. Author

Review: The essence of high reliability is attention to detail. This paper explains the kinds of details which are important in processing magnetic components. The paper is, of course, of value to those who are interested in magnetic components, but further it is of value to those who are becoming involved with any high-reliability application. As the paper shows, it is not enough to make a nominal design of a part which will work on bench tests, but it is important to consider every production detail. The several reviews which the design and production cycle receive are important and help assure the desired high reliability. Research and development people, who are all-too-prone to think that production just buys a few standard parts and throws them together, should read the paper carefully to realize that while their work is essential (as is any link in the chain), it far from completely specifies the nature of the item. That nature is influenced by the exact production techniques, the inspections, the acceptance criteria, etc. Designers can realize that their design is not complete until it specifies production sequences down to the last detail, and even then an interpreter is often necessary. This kind of design and review requires a coordination among the staff that is often not seen. Production engineers must be in on the design; test engineers must be able to say which kinds of failure modes are screenable and which kinds are not; statisticians can give an idea of the odds involved, etc. All in all, this is a good paper. It can be read profitably by all of those who are interested in high reliability.

R70-14916 ASQC 831; 431; 821

RELIABILITY DESIGN IN AN ELECTRONIC SWITCHING SYSTEM

Goro Tokuyama (The Electrical Communication Laboratory, N.T.T., Tokyo, Japan) *Electronics and Communications in Japan,* vol. 51-A, no. 12 Apr. 1968 p 36–44 8 refs

A reliability study conducted in the course of development and improvement of the DEX- 1 electronic switching system is presented. Described are the target operation probability of the switching system, estimation of the operating probability of each unit and its distribution, and especially the method of estimation when automatic diagnosis is involved. Subsequent discussion deals with the effect of call interruption on call mishandling probability during the equipment changeover upon failure. Author

Review: The topic of this paper is an important one and the kinds of analyses performed herein are conventional. A simple Markov process has been assumed for calculating the reliability of the Central Control (CC). The transition rates are presumed to be constant. The remainder of the calculations are very simple probability theory and presume that all the events are independent. Unfortunately, the original diagram with the transition rates is incorrect. Furthermore, the description is incomplete and not clear. State 3 (for each of the CC's) should be labeled "diagnosis completed, in repair." Of the possible sixteen states for the pair of CC's, six are equivalent to another six leaving only ten possible states. The author has eliminated the combined state 3,3 (both in repair) by asserting that as soon as one gets in the in-repair state, all other work ceases until the item gets repaired. By implication, the author has removed state 4,4 (both in manual diagnosis) since it is not in the listing of states; however, assumption 5 apparently allows it. Another point of difficulty is that if one CC fails, the other one performs the automatic diagnosis. Therefore, there can be no automatic diagnosis if both are down, and states 2,2 and 2,3 (the author's states 6 and 4) are not possible. Furthermore, the author has described some mean times as being the reciprocals of the transition rates. It should be emphasized that the transition rates in the matrix, which shows the transitions from one state to another and the nonallowed states, are the main quantities being defined. It is difficult to talk about *mean times* unless the states are carefully defined. It would be wise to use only the solutions to the differential equations for the states to calculate various *mean times* rather than to try to derive other equations. The calculations for the other parts were not carefully checked. All in all, the principles of analysis in this paper are correct. Their execution is faulty.

R70-14917 ASQC 837

OPTIMIZATION OF COMPONENT PART TOLERANCES

Tsutomu Hosaka (Electrical Communication Laboratory, N.T.T., Tokyo, Japan) *Electronics and Communications in Japan,* Vol. 51-C, no. 12 Dec. 1967 p 98–104 5 refs

Based on the worst-case circuit design, the author proposes a new method to decide optimally the allowable tolerances for parts or for major units of equipment. The proposed method assigns allowances to n parameters associated with a particular component subject to the required operational conditions, so that the yield of the component is maximized. Analyses are carried out subject to the assumptions (1) that all the parameters associated with a component are statistically distributed independently, (2) that the mutual relationships between the worst-case values of the cited equations, and (3) that the allowed tolerances are exclusively discrete, i.e., can have only certain stopped values. The method of analyses, categorized into the branch-and-bound method making use of the improvement limit of the target function, has the salient features that the method is effective under nonlinear restricting conditions and that all the optimal solutions are obtained through simple iterative computations. Author

Review: This paper is not clear, which may be due to a language difficulty. Because of this, the accuracy of the paper is hard to establish. Many of the terms themselves are not defined adequately. The following are examples. (1) ". . . allowed tolerances are permitted to exceed the prescribed discrete values, . . . ". It is

not clear how something can exceed a prescribed restriction. (2) The phrase "allowances of the parameters" is used, but its meaning is not given. (3) The variable yr is apparently the deviation of the parameter from its nominal value. It is later stated to be Gaussian and then even later stated to be normalized by the standard deviation. Yet equation 4 allows only positive values of y. (4) It is not at all clear where equation 5 came from, what it is supposed to do, or why it is used. (5) Apparently some of the variables are allowed to assume discrete values only. It is not clear how they can do this and still be Gaussian. (6) All variables are assumed to be statistically independent and yet if an upper and lower bound are necessary for the same variable, an auxiliary variable is introduced. It is not clear why the upper and lower bounds for the same variable should be statistically independent.

R70-14918 ASQC 830; 844

DAMAGE-TOLERANT DESIGN

Carl C. Osgood (Radio Corporation of America, Princeton, N.J.) *Machine Design* Oct. 1969 p 91–95 2 refs

A distinction is drawn between the two design philosophies of safe-life and fail-safe, which have evolved from the study and analysis of fatigue. It is also shown how these philosophies relate to three fundamental means available for controlling fatigue damage and operating lifetime. These fundamentals are identified as selecting materials and fabrication processes to satisfy governing specifications; establishing the quality level of the design to meet or exceed specifications; and keeping the operating stress level below the given limit. Four guidelines for fail-safe design are proposed: (1) The structure must have an adequate life, either as a crack-free period or one during which the growth rate of cracks is sufficiently low as to escape detection by inspection procedures. (2) The structure should be able to carry a predetermined load under a given amount of damage. (3) Visual inspection of all critical areas must be possible, either in service or after tests. (4) Repair of damaged elements must be accomplished either by replacement or by use of doublers. M.G.J.

Review: This is a good paper. It gives a fair description of both the safe life and failsafe concepts and also wisely explains that both are philosophical concepts rather than rigorously-defined mutually-exclusive theories of design. There is a minimum of jargon, at least for those with some background in fatigue. Electrical engineers will have greater difficulty in assimilating the points, but this merely reflects the fact that they have more to learn. The author makes the very good point that if you do not have some kind of inspection (ability to detect partial failures) then there is no point in failsafe design. All in all, for design and reliability engineers who are not very familiar with these concepts, this is a good paper to read.

R70-14920 ASQC 833; 844

DESIGNING RELIABILITY INTO RUBBER AND PLASTIC AC MOTOR CONTROL EQUIPMENT

John T. Carroll and Thad F. Bellinger (Allis-Chalmers Manufacturing Co., Milwaukee, Wis.) *IEEE Industry and General Applications Group Annual Meeting, Chicago, Sept. 29–Oct. 3, 1968) IEEE Transactions on Industry and General Applications,* vol. IGA-5, no. 4 Aug. 1969 p 455–464

The reliability of rubber mill control is achieved by the recognition of the operational and environmental needs of the equipment. Mature design, quality of material and workmanship, and ease of maintenance are intrinsic to the nature of a reliable product. Reliability is defined and its measurement and attainment in the process of preparing a product for manufacture is discussed. Practical examples are provided to demonstrate how the selection of basic materials, components, enclosures, and circuit arrangements enhance reliability. Author

Review: This paper has much wider applicability than the title would suggest. It is a good practical discussion which will be well worth the reading time for anyone having responsibility for the manufacture of reliable electric or electronic equipment. The first two sections consist of a fairly simple description of the basics of reliability analysis, including the definition of reliability, the role of the exponential distribution in dealing with failures which occur at a constant rate, and the use of Weibull graph paper in order to determine the applicability of the exponential distribution. (The latter is a step that is very often ignored in favor of a blind assumption that the exponential distribution is applicable.) The discussion does not sacrifice accuracy for brevity but does naturally leave out many details. The user interested in these details should refer to one of the textbooks which are available on the statistical aspects of reliability analysis (e.g. "Probabilistic Reliability: An Engineering Approach," by Martin L. Shooman; see R69-14176). No references are cited in the paper. Over half of the paper is devoted to a discussion of practical design considerations that enhance reliability. These include improved insulation materials, conductors and connections, component devices, control power and operating circuits, rectifiers, and protective enclosures. The summary at the end of the paper is in itself a good statement of some practical considerations involved in designing and manufacturing reliable equipment.

R70-14932 ASQC 838

Texas Univ., Austin. Electronics and Related Science Research Labs.

REDUNDANCY IN THRESHOLD LOGIC NETWORKS

James Daniel Bargainer and Clarence L. Coates Aug. 1966 106 p refs

(Contract AF-AFOSR-766-66)

(AD-488968)

Methods are presented for designing error correcting capabilities into threshold gate networks so that the logic gates themselves correct errors of the system. A method is first presented which is based on the tree method of Coates and Lewis for the realization of threshold gate networks. In this method, the error correcting network is designed from the Boolean function to be realized. A primary realization is a realization for some function on the tree such that either the separating function or the gaps are assigned without knowledge of any other realizations on the tree. It is shown that a realization obtained by the tree method will correct errors of gates in the system if and only if all primary realizations are selected so that they will correct errors of gates in the primary realization. Relations are then presented for selecting the primary realizations. In the second part of this paper, three methods are presented for adding redundancy to a given realization so that errors of gates are corrected by the level of logic immediately following the occurrence of the error. In the final section, it is shown that correcting errors in the logic gates themselves requires fewer levels of logic and, for many realizations, fewer gates than when majority gates are used to correct the errors. Author

Review: This report has only recently been released into the public domain. It apparently consists of the first author's Ph.D. dissertation and has the usual characteristics of such documents: it is quite long, well detailed, and presents the new material after

much introduction. This does not lessen its value, however, as the introductory material consists of a summary of the state-of-the-art and an explanation of the nature of threshold logic. The latter is very authoritative. On the negative side, the length, completeness, and mathematical detail do not make this thesis very useful as a quick review of the subject. The bibliography is surprisingly short, and the reader may wish to refer to the book on threshold logic which Dr. Coates co-authored [1] (and which was published after this report). For the reader who has difficulty with the explanations of threshold logic included in this report, there are very lucid ones in Chapter 6 of Pedelty's book [2]. The real value of this report lies in Chapters 3 to 5, and these are well presented. Notably, in Chapter 5 the proof that these threshold gates are superior to majority logic in correcting errors economically is very interesting. On the whole this work will be of great interest to the designer interested in reliable logic.

References: [1] Lewis, P. M. and Coates, C. L., *Threshold Logic,* John Wiley, New York, 1967. [2] Pedelty, M. J., *An Approach to Machine Intelligence,* Spartan Books, Washington, D.C., 1963.

R70-14941 ASQC 830; 844

Arizona Univ., Tucson. Engineering Experiment Station.

INTERACTION AMONG THE VARIOUS PHENOMENA INVOLVED IN THE DESIGN OF DYNAMIC AND ROTARY MACHINERY AND THEIR EFFECTS ON RELIABILITY

Annual Summary Report, 1 Feb. 1967–31 Jan. 1968

Dimitri Kececioglu and Edward B. Haugen 30 Apr. 1968 394 p refs

(Contract N00014-67-A-0209-0002)

(N69-11876; AD-671780)

This report contains the findings of a literature search with the following primary objectives: (1) to assess the state of development of the probabilistic design by reliability theory and methods as they apply to dynamic and rotary machinery, (2) to assess the availability of data in statistical form to support design by reliability applications; (3) to survey the extent and nature of the interactions among the design phenomena important to dynamic and rotary machinery, (4) to determine the gaps in the available design by reliability data and theory; (5) to recommend research that needs to to be conducted to fill in the gaps. Author (TAB)

Review: This book is written from a different point of view than most books which are concerned with mechanical design: it emphasizes the reliability analysis of a design wherein reliability is interpreted as a probability of failure. This is an important way of looking at mechanical design and one with which every designer should at least be familiar. Much of the book deals with conventional factors in design (at least they are conventional in this day and age), such as stress concentration, failure by fatigue, and how to combine multi-axial stresses. The latter discussions are quite straightforward and generally represent a reasonably agreed-upon method of handling these problems. The difficulties with both the probabilistic approach and the detailed conventional approaches which are given in this book are that generally one simply does not have enough data to use them completely. The subjective safety factors and engineering judgments which are deprecated in the old-time approach tend to be replaced by (1) other subjective factors and engineering judgments in the realm of confidence factors, (2) guessing at parameters of probabilistic distributions, (3) assuming that the probabilities out in the tails are given by the very tractable distribution used to describe the central portion, etc. Even if one could find all the handbook data he wished (and this is virtually impossible even if one is using something like MIL-HDBK 5), the designer tends to be piling guess upon guess, all of which are based upon guesses generated by handbook committees, etc., which have found their way into the literature. The question of whether or not handbook data apply to the next batch of metal that one gets is another problem. Castings are notoriously non-uniform and, for example, the ASM Metals Handbook shows sample distributions of the strengths of some cast irons, several of which are appreciably below their specifications. Material from steel mills is notoriously unpredictable, especially if one is trying to design without many fudge factors. There are not enough proven nondestructive test methods to demonstrate that a particular batch of metal received at your factory does have the mechanical properties you want it to have, especially those properties which relate to long life. It has been many years since it was insisted that one could not make useful predictions about reliability of electronic components unless one had all sorts of performance data in relation to time on the parts. In general, these data are still not available, and yet people have designed useful electronic systems which have had quite high reliability. This is done largely by avoiding the mathematics of reliability—except for the very elementary approaches—and concentrating on things like failure modes and effects analyses, stress to failure, and searching for potential weak points. The mathematics of reliability is not a design method. At best, it provides a framework within which a design can be analyzed. Some specific negative comments are given below. There is much in the book that is good, but, since one ordinarily tends to presume that a book can be heavily relied upon, only negative comments are given below. Some of the comments may turn out to be matters of taste rather than a matter of right/wrong. In that situation, the reader will have to use his own judgment. 1. Section 2.14–Another useful safety margin is

$$\frac{\bar{S}_f - \bar{s}_f}{\sigma_{Ssf}},$$

("mean strength minus mean stress" divided by "standard deviation of that difference")

This is the authors' z in Figure 2.6 on page 21. Very often this safety margin cannot be converted to a probability because the distribution is not well enough known in the tails. For example, the text says that the probability beyond the 4.5σ tail is $1.6 \times 10-5$, but in any distribution of real parts, the actual tail area beyond 4.5σ may differ considerably from this theoretical value. 2. Page 22. The ranges of S and s are not confined to being $(0, \infty)$ or $(-\infty, \infty)$. These are merely the two rough-and-ready sets of limits that are often used. 3. Page 46 (middle of the page). There is a discussion on when the *normal* distribution may be applicable. The same reasoning could apply to almost any other distribution. 4. Page 51. s_x is merely one of the estimators for σ_x. It is the one for which s_x^2 is unbiased. There are other estimators such as maximum likelihood. (Compare the authors' equation 2.39 with equation 2.26.) 5. Page 51. Equation 2.27 for f(x) should have an x in the denominator. 6. Page 52. The note to equation 2.29 is not clear. Also, it should refer to Section 2.2.3.2. 7. In the notation for equation 2.30, there is no need to restrict the location parameter to positive values, and usually the shape parameter is restricted to positive non-zero values. 8. Page 54. The equation relating the derivatives of G and F contains a misprint. The differentiation should be with respect to b on both sides. 9. Page 56, Item 5. It looks as if one random number is used for all of the variabes in this Monte Carlo procedure. This will cause extensive statistical dependence among the variates. Generally, one uses a separate random number for each statistically independent variable. 10. Page 58. The discussion of the maximum likelihood method seems to imply that maximum likelihood is the same as the method of moments. This is not so. 11. Page 59. The first derivation is traditionally much shorter. 12. Pages 59–60. See [1] and [2]; they should be read before read-

ing the authors' Reference 7. It is well known in statistics that the mean of the sum equals the sum of the means and that the variance of a sum is the sum of the variances and covariances, *regardless of the distributions of the random variables.* The formulas for multiplication and division on these pages are incorrect since the resulting distribution is not *normal.* 13. Page 61. Equations 2.48 through 2.57 are incorrect and should be disregarded. Some of them are true in the limit where the variances go to zero. 14. Page 63. *Equation 2.58 is true regardless of normality.* The only requirement is that the rest of the terms in the expansion be negligible; usually if the coefficient of variation is small, that will be true. 15. The square is missing from the last term in Equation 2.63. 16. Page 68. The authors keep emphasizing *normality* whereas it has nothing to do with the equations. 17. Page 74. Equations 2.76 and 2.77. These are incorrect since Q is a function of neither S nor s. Perhaps there is a misprint in some earlier equation. 18. Page 82. Point 5 is not valid. *It deals with the so-called algebra* of *normal* functions and contains the errors mentioned in comments 12 and 13 above. 19. It is common in books and papers such as this to deprecate the safety factors which have been used for a long time. It is true that those factors have many inadequacies. But it *is likewise true that they have served a very useful purpose and* that many times each day we trust our lives successfully to structures designed that way. While these safety factors can be considered to be very wasteful and so forth, one point often not taken into consideration is that we really do not know many of the *stresses to which the structure will be subjected.* All that we do know is the stresses which have been assumed in the conceptual model for the structure. Many many things being manufactured today (farm and road-building machinery for example) are probably subjected to many kinds of operation not desired by the designer. One of the things his safety factors do is take that into consideration. This is not to say that the old safety factor approach, especially where it is embedded in extremely old codes, should not be challenged, but it should be challenged realistically and not solely on the basis of oversimplified models. 20. Page 96. This table is most misleading except possibly for the first two entries. The assumptions are much too uncertain to permit calculation of the 0.01% tails. Factors such as the heat of steel, the heat treatment, and the *machining are all important and can easily override the* apparent precision of these numbers. 21. Page 99. Statements such as that which begins Section 3.4.1 saying that the tensile yield strength of an aluminum alloy is a random *normal* variable with a specific mean and standard deviation, are misleading in that *one is tempted to presume normality* far out in the tails. As has been emphasized in this review, it is just not known that this is so, especially not far enough in the tails to create a table such as referred to on page 96 in comment 20 above. Questions to ask are, "Does this variance hold for a particular heat of steel," "Does it cover year-to-year variations," and "Does it cover company-to-company variations." 22. Page 103. A calculation such as this from the B and A values in MIL HDBK 5 would be a reasonable thing to do if it were known that the distribution were exactly normal, and if the points on that *normal* distribution were known, rather than guessed at by means of confidence values. 23. Page 104. The first sentence of Section 3.4.1.1 stating that the mean and standard deviation do not uniquely define a distribution unless it is *normal* is incorrect. It would be difficult to find any reasonable two-parameter distribution which was not uniquely defined by them. 24. Page 111. Goodness-of-fit tests are a subject of some controversy among applied statisticians. Their utility is in question since among other things, where there are relatively few data, the hypothesis tends to *be "accepted"; where there are a great many data, the hypothesis* tends to be "rejected"; all regardless of the engineering utility of the distribution. 25. Page 117. The formulas associated with equation 3.16 are true only for a *normal* distribution. 26. Page 131. *A time-varying strength need not imply fatigue.* For example, corrosion could cause the strength to vary. 27. Section 11 does not mention the plastic-design for metals that has come to the forefront in this decade. 28. Section 13: Gaps in the Design by Reliability Methodology. This section does list some of the difficulties, but naturally enough it approaches the subject from the point of view of an enthusiast for this method.

References: [1] H. E. Reinhardt, Review of *Probabilistic Approaches to Design,* by Edward B. Haugen, John Wiley and Sons, Inc., New York, 1968, SIAM Review, vol. 11, Apr 69, pp. 292–294. [2] Professor Haugen has prepared a rebuttal to Professor Reinhardt's review. Readers who may wish to see this rebuttal prior to its publication may request copies from Professor Haugen, Department of Aerospace and Mechanical Engineering, The University of Arizona, Tucson, Arizona 85721.

R70-14946* ASQC 830; 821

OPTIMUM STRUCTURAL DESIGN BASED ON RELIABILITY AND PROOF-LOAD TEST

Masanobu Shinozuka and Jann-Nan Yang (California Institute of Technology, Jet Propulsion Lab. Pasadena, Calif.) *In: Proceedings of the Eighth Reliability and Maintainability Conference, Denver, July 7–9, 1969* Conference sponsored by the American Institute of Aeronautics and Astronautics, Society of Automotive Engineers, and the American Society of Mechanical Engineers New York Gordon and Breach Science Publishers 1969 p 375–391 13 refs

(A69-36033)

Description of an approach to structural optimization based on reliability analysis with emphasis on the use of the proof-load test. Depending on whether the structure is statically determinate or indeterminate, different methods of optimization are described. Numerical examples indicate that the expense of performing the proof-load test is always well compensated by the improvement of structural reliability due to such a test. In fact, under the constraint of the same expected cost, significant weight savings can be expected of a structure with proof-load-tested components, compared with the optimum weight of the structure consisting of components that are not proof-load-tested. The extent to which such an extra weight saving can be achieved depends on a parameter pertaining *to the importance of individual components relative to the cost of* failure. It is shown how the significant improvement of statistical confidence in the reliability estimate can be achieved on the basis of a proof-load test. The question of how to deal with the statistical confidence of the load distribution is also discussed at length.

Author (I.A.A.)

Review: The authors appear to have developed, for the analysis of a structure, a model which takes into account the probability of failure of elements, changes in that probability due to proof tests, cost, and weight. Obviously, some of these figures of merit can be generalized to other parameters. As the model is developed in the paper, the simple stress-strength model for failure is necessary (a stress above the strength results in failure; application and/or removal of a stress below the strength has no effect on the structure). This is so because if an item suffers cumulative damage, a proof-test as such is not feasible. It may be possible to extend the model to allow for cumulative damage and/or the proof test to be *nondestructive; and the authors have privately furnished references*

[1, 2, 3] to illustrate the extension to cumulative damage. Most models for failure of electronic parts are the cumulative damage type. The authors' suggestion for applying this method to very complex electronics systems must be regarded in light of the fact that the model is likely not to be applicable without considerable extension. The idea of using the information in the proof test to modify the probability-of-failure distribution is an excellent one. Much of the paper is involved with the mathematical techniques of finding the optimum point, and these will be most helpful to the nonmathematicians. This paper is a worthwhile addition to the literature on optimum design. Many design engineers will probably want to try it out at least in some simple cases to see what it can do for them. It can also be a spur to theorists to develop the theory in various other directions from this point. The discussion is rather tedious to follow because of the extensively defined nomenclature, but the model appears to be developed well from a mathematical point of view. Some points to keep in mind while studying the paper are listed below. (1) The concept of statistical confidence is mentioned several times, but it is difficult to apply the statistical meaning of that term to the cases the authors have in mind. Engineering confidence seems more appropriate. (2) The conclusions in numerical example #1 appear to depend strongly on the assumption that the cost of testing and possibly replacing a failed element is independent of its weight. Since the weight varies by a factor of 10 to 1, this will be unreasonable for very expensive elements. The authors state that the assumption of cost's being a constant for all components does not cause loss of generality. But this retention of generality is in illustration of the method, not in the answer; the answers are obviously highly specific on that assumption. For example, if the cost of replacement were assumed proportional to the weight and the cost of testing to be small, one would expect the cross-sectional areas to be proportional to the mean loads. (3) When the elements have bending or other nonaxial stresses, the authors' equations 3 and 23 should be carefully analyzed to be sure the assumption is adequately fulfilled. (4) The discussion of what to do in case "there is insufficient information on which to base the analysis" is conventional (as it was intended to be). One must be careful in using the loss and decision functions to make sure that they really express his feelings, because it is not one of the laws of nature that one must minimize an *expected* loss nor that the loss function be quadratic. (5) Even though the mathematical model developed in this paper appears to be a logically-consistent one, it is not necessarily applicable to any particular situation (the authors do not claim it is). A most important point is that the properties of a particular kind of material vary from lot to lot, and heat to heat; some of the properties fall below specification limits. One way to handle these problems is to perform the optimization calculation with various sets of possible parameters and see how widely differing the answers are. A sensitivity analysis could be performed. Furthermore, it pays to see how narrow or broad the minimum actually is. In some minimization problems, the parameters can be varied over wide regions around the optimum point without materially affecting the behavior. (This is true, for example, in the maximum power transfer theorem in electricity where the load resistance can be varied by a factor of 2 and reduce the power by only 11%. The authors have pointed out that their reference 6 shows that the optimum weight is rather insensitive to the analytic form of the distribution function.

References: [1] Freudenthal, A.M., and Payne, A.O., "The Structural Reliability of Airframes," Tech. Rep. No. AFML-TR-64-401, December 1964. [2] Freudenthal, A.M., and Wang, P.Y., "Ultimate Strength of Aircraft Wing," Tech. Rep. No. AFML-TR-68. [3] Heer, E., and Yang, J.-N., "Optimum Pressure Vessel Design Based on Fracture Mechanics and Reliability Criteria," Proceedings of the ASCE-EMD Specialty Conference on Probabilistic Concepts and Methods in Engineering at Purdue University, Nov. 12-14, 1969, pp. 102-106.

84 METHODS OF RELIABILITY ANALYSIS

R70-14903 ASQC 844

New York Univ., N.Y. Dept. of Aeronautics and Astronautics.

ON A CAUSE OF FAILURE OF HIGH ALTITUDE PLASTIC BALLOONS

Arnold D. Kerr and Harold Alexander Aug. 1968 25 p refs

(Contract F19628-67-C-0241)

(AD-692173; AFCRL-68-0486)

In search for causes of failure of plastic balloons, an experiment which simulates the stresses and temperatures in part of a balloon during launch and ascent was conceived and then tests using a number of balloon films were conducted. The test sample is a cylinder formed by heat sealing two long film strips along the edges. In the test the film cylinder, which is closed at both ends, is preloaded axially at a temperature encountered at launch, after a time interval cooled to −70F, and then pressurized until it bursts. Tests were conducted on samples made of StratoFilm 54 inch layflat tubes, DFD-5500 54 inch layflat tubes and DFD-5500 33 inch layflat tubes. All tested films were 2 mils thick. Author

Review: High altitude balloons are an important part of aerospace technology even though they are often overshadowed by some of its more glamorous aspects. This paper is of value to reliability engineers as an illustration of the application of physics of failure. It is more directly applicable to balloon designers and manufacturers in that it shows tests that can be performed to help ensure that the balloons will in fact survive the mission. The results were achieved without resorting to high-powered statistics or complicated mathematics and are typical of what can be done in improving reliability when engineers get bright ideas and implement them.

R70-14904 ASQC 844

New York Univ., N.Y. School of Engineering and Science.

A FAILURE STRESS CRITERION FOR A POLYETHYLENE BALLOON FILM

Harold Alexander and G. K. Narishma Murthy Jul 1968 29 p refs

(Contract F19628-67-C-0241)

(AD-69256; AFCRL-69-0103)

As part of a study of stresses and deformations of balloon films, 'safe' stress levels for polyethylene balloon films are established. Various methods for the determination of the yield point and yield stresses are reviewed and their applicability to balloon films are discussed. In the present paper a 'safe' stress level is considered as the one at which the material sample which creeps will not fail within a specified time interval. Creep tests were conducted with cylindrical samples that were pressurized and additionally loaded by a dead weight axial load. It was found that within a narrow range of stresses, the deformation vs. time curves change from those of uniform creep to curves which show a highly accelerated rate of deformation. The stress values at which this abrupt transition takes place are considered as the 'failure' stresses. Using this new failure criterion a 'safe' stress chart for 2 mil StratoFilm is presented and its applicability in design and analysis of high

altitude balloons is discussed. Author

Review: The direct transposition of concepts of failure in metals to plastics or electronics is not always feasible. This is because the failure behavior in nonmetals can be quite different. This paper is an example which shows that plastic film for balloons does not have the tensile strength characteristics of metals. As the authors point out, the viscoelastic nature of plastics is so pronounced that strain rate effects almost completely dominate the tensile characteristics, whereas for metals there is usually a very large range of strain rates over which the tensile properties are virtually the same. The authors have apparently succeeded in determining tests of the plastic films which do simulate the use conditions and are transformable to design considerations. If the principles involved in this paper are found to hold for other plastic films, the authors will have made a substantial contribution to the design of balloons and will have illustrated a good application of what many practitioners like to call *reliability physics.* When one thinks of reliability in aerospace engineering, one most often thinks of computers on space vehicles or something similar in the more glamorous phases of space exploration, but we are learning much about our earth with more conventional, much less expensive techniques of balloons. Therefore, progress in making balloons more reliable is a help to the practical utilization of aerospace technology.

R70-14906 ASQC 844; 775
SENSING RELIABILITY IN OPERATING EQUIPMENT
H. R. Hegner (IIT Research Inst., Glidden, Wisc.) and A. H. Hehn (General American Transportation Corp., Niles, Ill.) *(National ISA Aerospace Instrumentation Symposium, 15th, Las Vegas, 1969) Instrumentation Technology,* vol. 16, no. 10 Oct. 1969 p 85–91

An overview is presented on the advanced techniques and developments for continuously monitoring the reliability of nonelectronic systems. The methods described involve magnetic field signatures, eddy currents, electromagnetic energy scattering, acoustics, vibrational analysis, and chemical analysis. The performance monitoring technique permits the causes of failure to be pinpointed, particularly in cases where the interactive failure of many elements occurs thereby obscuring the prime cause. Author

Review: This paper presents brief descriptions of advanced techniques and developments for continuously monitoring the status and health of non-electronic systems. The methods involve magnetic field signatures, eddy currents, electromagnetic energy scattering, acoustics, vibrational analysis, and chemical analysis. These techniques are designed to monitor equipment continuously or at short intervals while it is in operation, with the objective of detecting symptoms long before a failure occurs. The advantages which these techniques have over preventive maintenance or periodic replacement of components are brought out clearly by the authors. The article is concise, well illustrated, and adequate to give the reader a good general picture of the capabilities of these methods. It does not provide details regarding the actual test equipment, nor are their economic feasibilities examined. This paper will be of value to those concerned with improving the reliability of hydraulic, pneumatic, mechanical, and electromechanical equipment.

R70-14909 ASQC 844
HIGH RELIABILITY ALUMINUM WIRE BONDING
C. Plough, D. Davis, and H. Lawler (Fairchild Semiconductor Corp., Palo Alto, Calif.) *In: Proceedings of the 1969 Annual Electronic Components Conference, Apr. 30–May 2, 1969* Conference sponsored by the Electronics Industries Association and the Parts, Materials and Packaging Group of the Institute of Electrical and Electronic Engineers Washington, D.C. McGregor and Werner, Inc. 1969 p 157–165

The important variables in aluminum ultrasonic wire bonding are grouped according to those which are most significant for the actual bond, and those which affect the wire strength. The variables affecting bond strength are identified as surface factors; contact and pressure; and energy applied, effectiveness, and quality. The variables affecting wire strength are listed as the type of wire, the size and shape of the tool, the bonding equipment, the bonding procedure, and the packaging. The bonding evaluation procedure is outlined. Equipment and tool evaluation is discussed in terms of the bonding machine, the quality of the wire used, and the selection of bonding tools. The criteria for establishing a bond strength test are detailed, and methods of control are described for achieving high reliability bonding. M.G.J.

Review: This is a good paper. It attacks one of the major causes of failure in semiconductor devices (poor bonds). Much of the work was done with an artificial system, but apparently the techniques developed have been satisfactory for actual semiconductor devices. The paper will be of most interest to reliability engineers and to those concerned with the production of semiconductor devices. Many of the curves will be useful for those who are trying to set up their own systems. The only kind of bonding dealt with is ultrasonic bonding and it is largely aluminum-to-aluminum, although there is some aluminum-to-gold. The paper can also be used to advantage by those who are trying to learn about ultrasonic bonding of aluminum wires in general.

R70-14910 ASQC 844
STRESS FAILURES AND JOINING CONSIDERATIONS IN HYBRID CIRCUITS
Sandford S. Cole and Alfred R. Kroehs (Alpha Metals, Inc. Jersey City, N.J.) *In: Proceedings of the 1969 Annual Electronic Components Conference, Apr. 30–May 2, 1969* Conference sponsored by the Electronics Industries Association and the Parts, Materials and Packaging Group of the Institute of Electrical and Electronic Engineers Washington, D.C. McGregor and Werner, Inc. 1969 p 298–303 2 refs

Fractures of capacitor chips, which have their origin in high stresses caused by thermal expansion mismatch, are assessed. Some of the possible stress states in hybrid structures are examined, and calculations are made to obtain a first approximation of stress levels. Typical physical properties of a 96% alumina ceramic and a titanate ceramic are tabulated. Several joining alloys are examined, which allow sufficient yielding to relieve critical stresses when used in hybrid circuits. Selection parameters for the bonding alloy are discussed in relation to stress considerations, metallurgical compatibility, and bonding time and temperature. It is concluded: (1) Thermal mismatches must be compensated to avoid capacitor fracture. (2) Compensation is best accomplished by using a soft solder alloy. M.G.J.

Review: This analysis considers the substrate, the ceramic chip and the intermediate adjoining material as a mechanical system. The fracture behavior of ceramics is discussed and the yielding behavior of the adjoining compound is emphasized. The discussion is good without too much technical jargon; semiconductor and electrical engineers should be able to understand it readily. Some of the simple mathematical models are applicable to more than just the specific case of capacitors on ceramic substrates, which is

treated in this paper. Reliability engineers ought to have an appreciation, at least, for this kind of discussion if they are involved with systems wherein the model is applicable. The few equations were not thoroughly checked, but they appear reasonable.

R70-14911 ASQC 844; 851

INVESTIGATION OF MICROCIRCUIT SURFACE METALLURGY

R. S. Buritz, A. Fafarman, R. F. McGowan, and S. L. Webster (Hughes Aircraft Co., Research and Development Div., Culver City, Calif.) *In: Proceedings of the 1969 Annual Electronic Components Conference, Apr. 30–May 2, 1969* Conference sponsored by the Electronics Industries Association and the Parts, Materials and Packaging Group of the Institute of Electrical and Electronic Engineers Washington, D.C. McGregor and Werner, Inc. 1969 p 304–321 15 refs

The problem of the development of open-circuits in the metallization of microcircuits is examined, and processing improvements to eliminate nonuniformities, voids and microcracks are reviewed. The basic failure mechanisms for these defects are analyzed, and essential additional testing procedures for defective metallization are worked out; these include thermalcycling-fatigue, high temperature electromigration and combinations of these stresses. The technique of accelerated testing is analyzed; this method can be used, e.g., to simulate the occurrence of failure for a 5 year space mission, within a much shorter test period. Estimates for the acceleration factor, attainable by increased temperature, are furnished.

Author

Review: This is a good paper. Reliability and semiconductor device engineers can profit from the material in it. The reliability problem is wisely considered to be largely an engineering/physics one and the statistics are used in support of the physical evidence rather than as the be-all and end-all of the program. The discussion of the various failure mechanisms under consideration is very good. A minimum of technical jargon is used, so that it will be reasonably understandable to many engineers. The discussion of accelerated testing and the Arrhenius equation is generally good. The only difficulty is that the activation energy is usually not accurately known, so that the acceleration factor is likewise not accurately known. This generally introduces a very large uncertainty into the extrapolated hazard rate, and it is always wise to estimate this uncertainty, since it can be as much as a factor of 10 or more. This was not done in the paper. When the random variable in an experiment is a discrete number (such as the number of failures in a given time), the confidence levels calculated are not exact but are generally lower bounds on the confidence level. Thus, on page 317 in the Table 1-1, the column could have been headed *"Minimum* Confidence Level." The experimental program is described well enough. Obviously in the short space, the authors cannot go into great detail. Device and reliability engineers who are concerned with semiconductors and their failure mechanisms would be well advised to be familiar with the contents of this paper. In a private communication, the second author has added that since the activation energy is 0.4–0.6, the 150C acceleration factor is between 30 and 160, and the failure rates should be multiplied by 0.4 and 2.3 to get the range of uncertainty. (The actual range is smaller since the acceleration of electromigration is only part of the test.)

R70-14912 ASQC 844

OPTIMIZING CYCLIC FATIGUE LIFE OF CONTROLLED COLLAPSE CHIP JOINTS

Lewis S. Goldmann (International Business Machines, Corp., East Fishkill, N.Y.) *In: Proceedings of the 1969 Annual Electronic Components Conference, Apr. 30–May 2, 1969* Conference sponsored by the Electronics Industries Association and the Parts, Materials and Packaging Group of the Institute of Electrical and Electronic Engineers Washington, D.C. McGregor and Werner, Inc. 1969 p 404–423 5 refs

The mechanical reliability of "controlled chip collapse" or "flip chip" bonded joints when a module is subjected to the thermal fatigue conditions of machine usage is presented. Particular emphasis is placed on product variability and how the shape and dimensions of the joint and chip affect reliability. A systematic technique is presented to optimize pad dimensions. A new experimental method to characterize chip-to-substrate interconnections–the torque test–is described. Its applicability to product evaluation is discussed and representative data analyzed. The relationship between torque test measurements and fatigue is discussed.

Author

Review: This very detailed paper considers the thermal cyclic fatigue of a particular solder bonding method and demonstrates that some of the principles of mechanical engineering are vitally important for electrical engineers. Not all of the equations and derivations were checked, but they appear to be competent. The mechanical behavior of semiconductor devices and their assemblies is extremely important and manufacturers of the devices are aware of this, as is illustrated by this paper. However, some reliability engineers, especially those new to the field and some design engineers may not realize the extreme importance of mechanical considerations. Furthermore, they may not even be familiar with the fact that such a phenomenon as thermal fatigue exists. While few people, except those who are directly involved in producing such bonds, will want to go through the analysis in detail, the main points in the paper are useful to reliability engineers. If nothing else, the paper can make them aware of the kinds of detail to which it is important to pay attention. Even though this bonding technique is not widespread among producers, similar situations can prevail so that the analysis is not as restricted as it might at first appear.

R70-14919 ASQC 844

PROGRESSIVE NATURE OF FATIGUE DAMAGE IN RP

T. R. Smith and M. J. Owen (Univ. of Nottingham, Dept. of Mechanical Engineering, Nottingham, England) *(Sixth International Reinforced Plastics Conference, London, Nov. 13–15, 1968)* *Modern Plastics,* vol. 46, no. 5 May 1969 p 128–133 3 refs

Using loss in modulus as a failure criterion to indicate that debonding had occurred, a series of fatigue tests were conducted on one fabric and two chopped strand mat (CSM) laminates, and one cross-piled nonwoven roving epoxy resin laminate. The mat laminates were subjected to fully reversed fatigue loading; the fabric and roving laminates to zero-tension loading. Resin cracking was detected optically in the glass mat laminates. Negligible difference in debonding performance was observed between the two different resin matrices in the mat laminates, but resin cracking was delayed in the low reactivity (LR) resin, probably reflecting the greater strain to failure of the LR resin. Fatigue damage in the laminates are depicted by S–N diagrams; results correlate on the basis of maximum strain. In general, it was observed that debonding occurred at higher maximum stresses in conjunction with higher mean stress levels.

M.G.J.

Review: This is a short well-written technical paper. A method for detecting internal damage by a change in modulus is presented along with fatigue design data (for four laminates) which would

allow design and materials engineers to analyze a design based on one of the following three damage criteria: (1) debonding at the reinforcement-resin interface, (2) resin cracking, or (3) total separation into two or more pieces. Such information is useful because of the inherent loss of properties in these materials with incipient damage. Test engineers who are concerned with reinforced plastics will also find the paper worthwhile.

R70-14921 ASQC 844; 775

INCIPIENT FAILURE DETECTION IN BEARINGS

Harvey L. Baldersten (The Boeing Co., Seattle, Wash.) *(National Fall Conference of the American Society for Nondestructive Testing, 28th, Detroit, Oct. 14–17, 1968) Materials Evaluation*, vol. 27, no. 6 June 1969 p 121–128 5 refs
(A68-44059)

Discussion of a bearing test program, in which three separate and distinct sources of acoustic energy were observed. These are (1) rotational noise, (2) reasonant noise of the bearing components, and (3) acoustic emission. It is shown that there is a direct relationship between the amplitude of rotational noise and defects in bearing surfaces, and between resonant noise and these defects. The rotational noise energy is distributed across a bandwidth from 60 to ≈2000 cps, while the resonant frequencies range between 10 and 50 kc. Most of the spectral plots obtained exhibit a blank space between 2 and 10 kc. This space can be considered as a divider between the rotational and resonant frequencies, including the drive-motor rotational frequencies and the shaft resonant frequencies in the rotational frequency band. By using this divider, it proved possible to detect the presence of "burst" pulses of acoustic emission. A direct relationship between the severity of the defects and the amplitude could be observed between specific bandwidths, and also between the severity of defects and total noise. I.A.A.

Review: As the author of this paper points out, subsystems capable of detecting the basic causes of incipient failure can enhance the reliability and the maintainability of any operational system to which they are applied. This paper is a detailed discussion of the problem of detecting incipient failure in bearings, and consequently is applicable to a wide class of rotating equipment. Three basic sources of noise in bearings are described, namely, (a) *frequencies of rotation, (b) resonant frequencies, and (c) acoustic emission*. This is followed by a discussion of four examples in which known defects were present, displaying the power spectral density versus frequency signature in each case. An important feature of this work is the employment of the resonant frequency band rather than rotational frequencies to detect incipient failure. It is expected that the use of the acoustic emission phenomenon will become more important with further developments. The paper is well written, clearly illustrated, and conveys a great deal of information in a few pages. For those who desire more details, five references are cited.

R70-14922 ASQC 844

ANALYZING DIESEL ENGINE FAILURES

Roger C. Tittel (Cummins Engine Co., Inc., Columbus, Ind.) *Metal Progress*, vol. 95, no. 4 Apr. 1969 p 74–78

Design, materials, manufacturing, application, maintenance, and operation are identified as the main sources of diesel engine failures, and the factors which must be considered in each area are discussed. Several examples of field failures are given, together with the remedial action undertaken to correct such defects. M.G.J.

Review: This is an excellent short article on the causes of *failures in diesel engines*. It indicates that the major sources of problems are (1) design, (2) materials, (3) manufacturing, (4) application, and (5) maintenance and operation. These sources of problems apply to any type of hardware, of course, and the paper illustrates the importance of knowing the overall system well enough to be able to identify the sources of the difficulties which arise. Those interested in fatigue failures will find a number of *clearly-illustrated examples* in the paper.

R70-14924 ASQC 844; 775

DETECTION OF STRAIN BY COHERENT OPTICAL TECHNIQUES

K. C. Chuang and R. K. Mueller (Bendix Corp., Research Labs., Southfield, Mich.) *(National Fall Conference of the American Society for Nondestructive Testing, 28th, Detroit, Oct. 14–17, 1968) Materials Evaluation*, vol. 27, no. 4 Apr. 1969 p 76–78 12 refs
(A69-26305)

Description of the utility of holographic interferometry, optical correlation, and diffraction for surface microstrain measurements and flaw detection. The key to holographic interferometry is the use of a hologram to reconstruct a three-dimensional image at the original object position. In optical correlation, the characteristics of the spherical lens are utilized in conjunction with holographic recording of phase and amplitude. Strain measurements based on the optical diffraction grating require a giant-pulse laser for engraving the grating and a CW gas laser to serve as a monochromatic light source of diffraction. Coherent optical techniques for strain measurements are noncontacting, highly sensitive, and permit the determination of strain gradient in both static and dynamic conditions. I.A.A.

Review: The stated purpose of this paper is to summarize recent progress in the application of coherent optical techniques to strain detection, and that purpose has been accomplished quite well in a clear and concise presentation. For a full appreciation of how these techniques work, the reader will need a background in optics, particularly interferometry, and some knowledge of the capabilities and operation of lasers. However, for the design and reliability engineer, the important contribution of the paper is to convey an awareness of the existence of these new nondestructive inspection techniques. The authors emphasize the noncontacting nature of this tool and also its sensitivity. They discuss the use of the diffraction grating as a strain gauge, which use has been assisted considerably by the development of the laser. There is no description of available test equipment or of the cost of such equipment. In summary, the paper is a brief description of the capabilities of these techniques. Twelve references are cited for those who may *desire more details.*

R70-14925 ASQC 844; 775

HOLOGRAPHIC NONDESTRUCTIVE TESTING HNDT

R. M. Grant and G. M. Brown (GC Optronics, Inc., Ann Arbor, Mich.) *(National Fall Conference of the American Society for Nondestructive Testing, 28th, Detroit, Oct. 14–17, 1968) Materials Evaluation*, vol. 27, no. 4 Apr. 1969 p 79–84 4 refs

Details are given on a holographic nondestructive testing (HNDT) technique, which combines three-dimensional laser holography and laser interferometry. This permits the detection of material defects and the measurement of significant material strength properties. Holographic interferometry is based on the fact that the reconstructed holographic wavefront contains phase information, so that two or more simultaneously reconstructed

wavefronts can be compared. It is pointed out that the reconstruction stage can be likened to a three-dimensional Michelson interferometer. The equipment and techniques used for HNDT of pneumatic tires, sandwich structures, and aircraft brake disks are described, and the application of this method to corrosion and erosion rate measurements and the evaluation of creep under static load is discussed. It is concluded: (1) Holographic NDT is a practical and versatile tool for quality control and design. (2) Large areas can be inspected quickly, a variety of flaws can be detected simultaneously, and a choice of several low-level stressing methods is available. M.G.J.

Review: This paper demonstrates with selected examples the fact that holographic nondestructive testing has been developed to the point that it is now a practical and versatile tool for quality control and design. You should beware that any application of this tool is still likely to consume large amounts of time and money and to require trained people—especially if it is the first application for your organization. Prominently featured in the examples is a Holographic Tire Analyzer, but reference is made also to measurement of corrosion and erosion rates and evaluation of creep under static loads. There is a good brief general description of how holographic nondestructive testing works, which can be appreciated by anyone with a background in basic optics, including interferometry, and some knowledge of how a laser works. However, the main purpose of the article is not the conveying of this information, since the emphasis is on applications. These can be appreciated best from photographs which are included in the paper. There are also some photographs of test equipment, and brief reference to these is made in the text. However, no detailed descriptions of test equipment are given nor is there any indication of the costs of such equipment. No references are cited. The reader interested in this topic will wish to see also the paper by Chuang and Mueller which precedes this one in the same journal.

R70-14927 ASQC 844
Rome Air Development Center, Griffiss AFB, N.Y. Research and Technology Div.
RELIABILITY PHYSICS STUDIES ON TRANSISTORS
W. Schroen June 1966 158 p refs
(Contract AF30(602)-3605)
(AD-487386; RADC-TR-66-157)

This report is divided into two main sections, both concerned with reliability physics studies on transistors. The first part describes investigations of two surface failure modes, namely surface breakdown phenomena in silicon planar devices, and effects of mobile surface ions located on silicon oxide surfaces. The surface breakdown voltage of a diode can be altered by non-equilibrium carriers which are generated by external illumination or moving in surface channels. A model is investigated which considers the non-equilibrium carriers as additional charges in the space charge region. According to this model, the maximum reduction of breakdown voltage is achieved when the external light spot is shining on the edge of the space charge region. Calculations are presented concerning the influence of non-equilibrium carriers on the breakdown voltage. The investigations of mobile surface ions were concentrated on measurements of the accumulation and the decay of surface ions as a function of time and position as to the junction. The influence of chemical treatment has been studied in detail. Measurements have been performed comparing QA and QK charge values with shifts of the capacitance-voltage curve. Parameters of these measurements were oxide thickness, oxide preparation, and temperature. The results have a direct bearing on the reliability of MOS structures and oxide protected devices. Author (TAB)

Review: These reliability physics studies include breakdown on the surface of silicon planar devices, the effect of mobile surface ions on a silicon oxide surface, and second breakdown (the last is an internal bulk failure mechanism). This report combines both experimental and theoretical work in order to gain an understanding of what is going on. The report does not deal with manufacturing techniques to eliminate these causes of failure. (This report only recently had its distribution limitation removed and so is current as far as the unrestricted literature is concerned.) The report is of value largely to those in applied physics of semiconductors. Certainly the knowledge included here can be helpful in eliminating causes of failure in silicon devices. The very basic work in all three areas has been done before, and the work described in this report builds on that and goes into more detail. The models being used now are less elementary than before. Failure analysts will also find this report helpful insofar as their research and work is more basic. Sponsoring this kind of work is important even though the output is not dramatic in terms of new devices. An earlier report on the same contract was covered by R67-13425.

R70-14934 ASQC 844
Air Force Systems Command, Wright-Patterson AFB, Ohio Foreign Technology Div.
METAL FATIGUE IN AN AIRCRAFT STRUCTURE
P. S. Shevelko Nov. 1968 84 p refs Transl. into ENGLISH from Russian publ.
(Contract F33657-68-D-0865)
(AD-683947; 65-AM7032404)

This book, intended for professional readers, introduces the problem of metal fatigue in aircraft structures; describes some physical bases for fatigue processes which take place in airplane structures; and makes recommendations how to avoid formation of metal fatigue while the airplane is in service. Modern methods of detection of fatigue cracks are described. Research materials, both Soviet and foreign, were used in this study. Author

Review: This short book is a good tutorial discussion about the fatigue of metals in aircraft. It is suitable for reading by engineers who have not had formal course work in fatigue, and it covers topics such as acoustic fatigue, the physical explanation of fatigue, and means of sensing fatigue cracks in structures. The book shows (as would have been expected) that the Russians have a good grasp of the factors which cause fatigue in aircraft and that they can explain it well. For those who have easy access to this book, it will be as good as any American text of equal length. There are no design details or information given. Its purpose is to give designers an understanding of the principles involved, not to give them a cookbook for designing to prevent fatigue. It serves its purpose well.

R70-14939 ASQC 844
Air Force Systems Command, Wright-Patterson AFB, Ohio. Foreign Technology Div.
FATIGUE OF ALLOYS AT HIGH TEMPERATURES IN STATISTICAL ASPECT
S. V. Serensen and L. A. Kozlov Nov. 1966 17 p refs Transl. into ENGLISH from the book "Termoprochnost Materialov i Konstruktsionnykh Elementov" Kiev, Nauka Dumka, 1965 p 137–146
(N69-32615; AD-686087; FTD-MT-24-355-68) Avail: CFSTI

Investigations were made into the characteristics of the statistical distribution of the fatigue properties and their parameters; the relation of these parameters to the stress level, temperature, and asymmetry of the cycle; the statistical evaluation of fatigue resistance during unsteady state loading; and calculations for

strength. The role filled by technological factors during statistical evaluations of mechanical properties is indicated. During observations of the appropriate level of treatment it was found that the differences in the fatigue life for parts of machines were less than for test samples made of the same material. Use in the computations of the mechanical characteristics with their statistical evaluation by means of test samples adds to the safety margin for strength when making calculations for the given probability of survival.
Author (TAB)

Review: This is an interesting paper and gives useful data about the fatigue properties of alloys at high temperatures. There is an admirable concern with the scatter in fatigue properties, and the authors confirm the fact (reasonably well substantiated at ordinary temperatures) that the scatter in the fatigue behavior of manufactured parts is less than that of smooth test specimens. The paper is not easy to read. For example, the word "deflection" means "deviation from mean value" rather than "a maximum elongation or movement of the specimen"; "prolonged static strength" means "creep". It would be worthwhile if someone were to make a more adequate translation of the paper since this appears to be more than just run-of-the-mill discussion. Some cumulative damage studies were run using the linear theory. Unfortunately, it is difficult to interpret the results from this translation. Apparently, the linear cumulative damage (or some simple modification thereof) was found to be satisfactory. For some of the tests, the wave shape of the applied stress was found to be not a factor in the life but in some other tests, it was a factor in the region where creep is important.

R70-14942 ASQC 844

Hughes Aircraft Co., Culver City, Calif. Electronic Properties Information Center.

FAILURE MECHANISMS/MODES IN MICROELECTRONICS INTERIM REPORT

John T. Milek 6 Mar. 1969 25 p refs
(Contract F33615-68-C-1225)
(N69-37477; AD-689756; EPIC-IR-64) Avail: CFSTI

The report presents a review of the modes of failure in various types of microcircuits. A bibliography is included. TAB

Review: While the title of this report implies that it could be important to designers of reliable electronic equipment, the information contained in the report is superficial, second-hand, and dated. The organization of the report is disjointed and broken. Readers seeking an introduction to failure mechanisms in microelectronics should consult other specifications such as the report by Shurtleff (NASA CR-1347; N69-23226) which is also reviewed in this issue of RATR.

R70-14950 ASQC 844

Texas Instruments Inc., Dallas

RELIABILITY HANDBOOK FOR SILICON MONOLITHIC MICROCIRCUITS. VOLUME 2: FAILURE MECHANISMS OF MONOLITHIC MICROCIRCUITS

William O. Shurtleff Washington NASA Apr. 1969 35 p refs
(Contract NAS8-20639)
(N69-23226; NASA-CR-1347; Rept-03-67-04-Vol-2) Avail: CFSTI

Defects are enumerated that are introduced into monolithic microcircuits during the various processes of manufacture; the impact of these defects on microcircuit failure rates and the techniques that are used to correct or remove the defects from the processes are considered. The techniques of processing that are used in the manufacture of monolithic microcircuits are sophisticated, numerous, and complex. There is a finite probability that defects are introduced at each step of the manufacturing process. These defects are of concern to both the manufacturer and the user of monolithic microcircuits in two major respects: (1) Defects reduce the effective yield of the manufacturer, thereby increasing the cost of each microcircuit bought by the user, and (2) Defects may cause microcircuit reliability problems which adversely affect the user's end product and the reputation of the microcircuit manufacturer.
Author

Review: This report is authoritative, up to date, and original. The latter quality is hard to achieve in a field as well ploughed as failure mechanisms in silicon circuits. The author attempts to reduce large amounts of failure experience and data into a few simple conclusions. This is a bold attempt to bring order to a complex subject, and makes for fresh reading. Whether he oversimplifies or not is unimportant as he has done an excellent job of reviewing the subject. The author's Table 2 gives a breakdown of the sources of silicon monolithic circuit failures. This 1969 tabulation presents few surprises; wire bonds cause the most failures; oxide defects (pinholes) are second, reversing the order of these failure sources published in 1965 by Browning. The report is not without its flaws. Table 1 contrasts the probability of escape of various defects with and without screening. Inexplicably the probability of escape (%) of "Parasitics, isolation" rises from 0.00 under no screening to 0.020 with screening. This number is a significant fraction of the total probability of escape (0.080) for the screened units, and is the only defect whose probability of escape rises with screening. No discussion of this anomalous behavior appears in the text. The numbers in Table 1 are probably in error; if not, surely further explanation is in order.

R70-14953 ASQC 844; 841

"IN-CAR" FATIGUE DATA ACQUISITION

F. R. Holliday and C. R. Allmen (Chrysler Corp., Engineering Staff, Detroit, Mich.) *International Automotive Engineering Congress, Detroit, Jan. 13–17, 1969* Paper 16 p refs

"In-car" measurement of vehicle loads and stresses is a basic step in solving fatigue design problems associated with passenger cars. The application includes measuring systems and techniques for evaluating fatigue design problems related to energy-absorbing steering columns and automotive gas turbines. Author

Review: This is a good, practical paper. The authors show the proper place for theoretical calculations and point out that almost regardless of the effort put in on them, they cannot be exact enough for all design purposes. This is due largely to lack of detailed knowledge of stresses and strengths for complex parts. Some articles on mechanical design and reliability give the impression that these things can be calculated with sufficient accuracy. It is good to see these authors putting analytic techniques in their proper perspective. As the title suggests, most of the problems are concerned with fatigue. Even though this is an automotive application, the same kinds of problems appear in aerospace hardware (in fact, one of the illustrations is a gas turbine). There is negligible technical jargon used, so the results are understandable by most anyone with some mechanical experience. The difficulties involved with instrumentation are brought out in a very practical way. Perhaps the best thing about the paper (and the most useful one for reliability and design engineers) is the excellent balanced emphasis it gives to the techniques available to a research and development group—going from analytic calculations to instrumentation of the part in service. The reliability field unfortunately contains people,

even prominently placed, who do not appreciate the balanced emphasis as shown by these authors. More of this kind of paper is necessary to counterbalance those who have over-emphasized the statistical nature and analytic nature of reliability.

R70-14954 ASQC 844
IS THERE ANY CORRELATION BETWEEN FLAWS AND SERVICE PERFORMANCE?
R. Halmshaw (Ministry of Defense, Fort Halstead, Sevenoaks, Kent, England) *Materials Engineering Exposition and Congress, Detroit, Oct. 14–17, 1968, Paper* 21 p refs
(TR-D8-10.4)

Studies of failures in service suggest that a large proportion of these is due to mistakes in design or to the use of wrong material, e.g. wrongly heat-treated steel, or steel used at temperatures below the brittle/ductile transition region. Relatively few examples have been traced in which failure can be shown to be due to flaws which would be found by conventional NDT methods applied before service. Various examples are described. Similar evidence is accumulating from work on flaws in welds, where much more work has been done, and some conclusions are drawn from this work. It is suggested that an acceptance standard for flaws in castings, if it is to have any scientific basis, must take account of casting shape, material and stressing. It must therefore be individual to a particular design of casting and cannot be a general standard. Author

Review: This is a good short, easy-to-read paper with a definite message. The message is implicit in the answer to the title of the paper and essentially says that very few flaws that get by any gross inspection procedure are likely to cause failure in industrial/commercial service. (Presumably the author means this to be true regardless of whether or not a particular failure did originate at a flaw.) Furthermore, he feels that few failures in service are caused by flaws which would have been found by nondestructive evaluation (NDE) methods. The author treats a serious problem in NDE today because the NDE methods are becoming so sensitive that harmless flaws can easily be detected. Yet specifications which were written earlier when only the more gross dangerous flaws could be detected, and are still invoked, require removal of parts with detectable flaws. Even though some would argue with the all-inclusiveness of the author's conclusion, few can dispute the fact that in many situations it is true. In summary, this paper has the excellent attributes mentioned in the first sentence of the review. It can be read easily by managers and others with non-technical backgrounds and will convey useful information to them.

R70-14957* ASQC 844
CORROSION FAILURES OF SPACECRAFT HARDWARE
Alfred J. Babecki (NASA-Goddard Space Flight Center, Systems Div., Greenbelt, Md.) *Metals Engineering and Pressure Vessels and Piping Conference, Washington, D.C., Mar. 31–Apr. 2, 1969* Paper 7 p

A number of corrosion failures that occurred in spacecraft hardware during fabrication, processing, or testing is described. The failures include those caused by stress corrosion, galvanic corrosion, liquid metal corrosion, corrosion fatigue, and atmospheric corrosion in such hardware as deck panels, solar cell interconnects, printed circuit boards, coil springs, brazed joints in tubing, flexure springs, and electrical connectors. Author

Review: One of the things that makes high reliability difficult to assure is that there are myriads of potential failure mechanisms in many components. The majority of these are probably well known, i.e., given that the failure mechanism is occurring, a competent engineer or scientist would say that he would have expected it. The difficulty is to make that prediction ahead of time by means of paying attention to an extremely large number of very small details. This paper concerns one type of such detail, that of corrosion. The paper graphically illustrates some unexpected kinds of corrosion (unexpected in the sense that no one looked for them), and what was done to solve the problem. As the author points out, many kinds of corrosion which occur in ordinary earth applications cause no difficulty and are not considered major defects. In space hardware, however, the defects may be major. For those design and mechanical engineers who are not familiar with the peculiar problems of corrosion in space hardware, this paper is a short easily readable description of the kinds of things which must be guarded against.

R70-14958 ASQC 844; 775
USE OF ACOUSTIC EMISSION TO STUDY FAILURE MECHANISMS IN METAL
Philip H. Hutton (Battelle Memorial Institute, Pacific Northwest Labs., Richland, Wash.) *Metals Engineering and Pressure Vessels and Piping Conference, Washington, D.C., Mar. 31–Apr. 2, 1969, Paper* 5 p refs

Acoustic emission as the elastic wave produced in metal by energy imparted as the metal deforms and fractures is defined. This study declares that use of acoustic emission gives a much greater degree of resolution in surveillance of metal deformation and cracking than any other available technique. The nature of acoustic emission is discussed, its detection, and use of the information for flaw detection and evaluation, as well as applications of the technique for detection of stress-corrosion cracking, weld cracking, metal fatigue, and flaw growth in pressure vessels. Author

Review: This good introduction to acoustic emission describes a technique which is still in the research-development stage although it has been applied successfully to a few problems. Some knowledge of the behavior of materials is required to understand the paper, but anyone who would be applying this technique would have such knowledge anyway. Unfortunately, the paper contains only a very few references for further information. The author stresses the fact that the method can be extremely sensitive. As these more sensitive methods of detection become available and in use, there is a growing difficulty in the field of nondestructive inspection for reliability. In the past, the techniques were generally so coarse that anything that was detected would adversely affect the reliability. But nowadays, it is not difficult to detect deviations from the ideal state which are so small that they will not have any appreciable effect on the reliability; therefore they ought not to be cause for concern or rejection of the piece. Thus both the specifications for rejection need to be written more precisely, and the technology needs to be developed to interpret the inspection results judiciously. Detection of fatigue cracks in aerospace structures, especially doing it when the cracks are extremely small, is a vital part of any reliability/maintenance program. Several techniques for detecting these cracks are in use, but none are entirely satisfactory. Perhaps acoustic emission can be used to simplify the maintenance/inspection procedures. Anyone interested in using acoustic emission to solve a problem should be aware that it may well involve a large research and development expenditure.

R70-14961 ASQC 844
Aeronautical Research Labs., Melbourne (Australia).
THE EFFECT OF THE INITIAL RATE OF LOADING ON FATIGUE LIFE
R. C. Beckett Oct. 1968 16 p refs
(N69-25492; ARL/SM-331) Avail: CFSTI

Rotating cantilever tests on notched and unnotched 2024 aluminum alloy specimens were made to check the effect on fatigue life of rates of application of test load of 15 p.s.i. and 560 p.s.i.

per cycle. Contrary to previous reports no significant effect was found. Author

Review: The effect due to the rate of initial loading may be related to the concept of cumulative damage. For many materials under a programmed two-level load, the results are different when the high level is run first than when the low level is first. This investigation was an interesting one although of value to theorists rather than designers. The experimental results, and the author's interpretation of them, appear quite reasonable. The only odd thing about the results is for unnotched specimens where the lives at the lowest stress appear somewhat less than at the next higher stress. Just looking at the graphs, one would have expected that at the lowest stress for unnotched specimens, they would have been mostly run-outs. The author has done unusually well with his statistical analyses. When running 22 tests, one is not at all surprised to have two of them show significance at a 90% level, one at a 95%, and one at a 99% level. In fact, if similar results were not obtained, one would be surprised. This is a trap the unwary often fall into–they run a great many tests, find a few "statistically significant differences," and are tremendously impressed with the result. The author's interpretation of "no difference due to rate of loading" is appropriately cautioned by his pointing out that it may hold only for the specific conditions of his test.

85 DEMONSTRATION/MEASUREMENT

R70-14908 ASQC 851; 224
AN IMPROVED ALL-EQUIPMENTS RELIABILITY TEST PLAN
L. Sessen (Fort Monmouth, USAECOM, N.J.) and R. Neathammer (Naval Ammunition Depot, Quality Evaluation Lab., Crane, Ind.)
Evaluation Engineering, vol. 8, no. 5 Oct. 1969 p 6–8, 50
(A69-43203)

Description of an improved All Equipments Test which uses the accept-reject lines of Test Plan III, MIL-STD-781, with the usual truncation removed and the "accept-reject lines" extended. The reject region remains the same, but the "continue testing region" becomes the "accept region" and the "accept region" becomes an "out-of-bounds region." The "accept line" becomes the "boundary line." Thus, equipments are acceptable until the "reject line" is crossed. The failure-versus-test time plot is not allowed to cross the "boundary line," but when reaching the "boundary line" it must follow this line so long as its slope would be less than the "boundary line." I.A.A.

Review: The proposed test appears to represent some appreciable ingenuity on the part of the authors, but unfortunately is not clearly explained, especially for those who are not extremely familiar with the other reliability test plans. The old test is based on the assumption of a strictly exponential distribution; no initial period of high hazard is considered in the model. The new boundary line (which has replaced the old accept line) performs its function in the following manner. When a point would fall in the out-of-bounds region, it is plotted on the boundary line at the correct test-time location. This is equivalent to accumulating failures at the failure rate corresponding to the slope of the boundary line. The authors have worked out some operational characteristic curves for this test and have plotted them on a rather detailed graph. Several things are not clear in the paper. The following are examples. (1) On that graph, it is not clear what kind of process was simulated. Presumably a straight exponential process was involved without any infant mortality; so it is not clear how the test would behave in the presence of infant mortality (the thing it was supposed to account for). On the same graph, some of the nomenclature is not clear (the θ should be θ_0–the specified MTBF). (2) Usage of the phrases *inherent MTBF* and *"predicted MTBF"* is not clear. *Inherent MTBF* is sometimes used as a synonym for *predicted MTBF*. This graphically illustrates the difficulty with the term *inherent MTBF* and the whole reliability community would be much better off if it were forgotten. (3) It is not clear what is meant by latent defects. Presumably, they are meant to be the kind that will cause infant death, not the kind that will cause adult death, although the two categories are often difficult to tell apart. This test is interesting. It appears to involve new and original concepts by the authors so it would be helpful if it were explained more fully and clearly.

R70-14926 ASQC 851; 844
Philco Corp., Lansdale, Pa. Microelectronics Div.
THIN FILM ACCELERATED LIFE TESTS
M. J. Walker and M. Sharp Griffiss AFB, N.Y. RADC Oct. 1966
218 p refs
(Contract AF-30(602)-3287)
(AD-803767; RADC-TR-66-180)

The purpose of this program was to study, investigate and develop test and measurement techniques for controllably accelerating the aging processes in tantalum thin film R-C networks, and to investigate the physics of failure associated with the networks. Construction and accelerated stress testing of tantalum thin-film resistors and capacitors and resistor capacitor networks was conducted to establish a means of predicting use level failure rates and to determine the failure modes and mechanisms associated with these networks. Most of the work was performed on networks formed on silicon substrates. Ion migration, crystallization and oxidation have been identified as the failure mechanisms. Acceleration factors have been determined from preferred stress levels and related to normal use conditions. Author (TAB)

Review: The thin films referred to in the title are of tantalum and its oxides and include resistors and capacitors. (The distribution limitation on this report was only recently removed and thus the report is current as far as the unrestricted government report literature is concerned.) The report is quite detailed, and all of the numerous tests and the devices are explained well. Statistics seems to have been used as a reasonable engineering tool rather than as an end in itself. Accelerated testing is the subject of some controversy and again this report treats it well–largely as an engineering tool. Much of the report is concerned with what is now called *reliability physics,* although it is treated as part of the engineering development rather than as a completely separate topic. All in all, this is a good comprehensive report, and those involved with tantalum film devices are advised to be familiar with its contents. An earlier report on this project was covered by R67-13361. The first author, in a private communication, has pointed out that thin film resistors have increased in importance since the report was written. This is due to requirements for radiation-hardened monolithic integrated circuits. He has called attention to the importance of metal film resistor reliability in this application and the fact that tantalum film resistors are now being used in radiation-hardened microcircuits.

R70-14940 ASQC 851
Motorola, Inc., Phoenix, Ariz. Semiconductor Products Div.
MICROELECTRONIC INTEGRATED CIRCUIT ACCEL-

ERATED LIFE TESTS
K. R. Mac Kenzie Jan. 1969 158 p
(Contract AF-30(602)-3299)
(AD-809281; RADC-TR-66-64)

The advent of the integrated circuit as a design vehicle in the more sophisticated systems had led to many assumptions concerning their physical cause of failure. The methods of stressing monolithic integrated circuits reliability degradation models as developed from stressing 2000 circuits is the subject of this report. Among the many stressing techniques used in this program was the long-term operating life testing at several temperatures and biases. Other techniques, such as long-term storage life testing, mechanical shock, centrifuge, thermal shock, and step stressing, supplemented the basic testing technique. Its most important contribution to reliability was in its evaluation of three types of basic operating life test models, its verification that previous discrete silicon transistor failure modes are still applicable, and that more extensive use of thin metallized interconnection strips has required more sophisticated process controls. The testing emphasis explored the physical cause of failure and the problem of accelerated stresses to some assumed use condition. Author

Review: Accelerating the life tests on integrated circuits is a problem that has been challenging the industry ever since integrated circuits were developed and shown to be at least as reliable as single semiconductors. This report has only recently been released for distribution through the CFSTI, and thus publicly shows some of the results that have been obtained. The most promising test consisted of applying usual voltages to the device and increasing the ambient temperature in order to produce a reasonable number of failures. Even so, the failure rates are reported to be insufficient for proving desirable failure rates at usual operating conditions. The integrated circuits which were tested are much simpler than many of those being made today, but certainly the difficulties in accelerated testing of the newer ones have not been alleviated, but rather have been exacerbated. A large portion of the program used accelerated testing in order to find screenable defects and to discover processing discrepancies and inadequacies which could be corrected. This application of accelerated testing is extremely useful and not subject to much controversy. The other use of accelerated testing, that of being able to extrapolate back to usual conditions, was also explored in this project, and some curves are given. This process has many statistical difficulties including those of calculating the uncertainty in the extrapolation, not to mention the difficulties with physical interpretation and adequacy of the conceptual model. Nevertheless, this aspect of the program is not overemphasized in the report. Even though some of the material may be out of date for those who had access to the restricted-circulation document, the material in this report is still valuable and useful to reliability engineers and designers of microelectronic devices.

R70-14952 ASQC 851; 844
RELIABILITY OF INSULATORS
D. Riviere (Institute of Electrical and Electronics Engineers, Sediver, Paris, France) *IEEE Winter Power Meeting, New York, Jan. 26–31, 1969 Paper* 7 p refs

This paper deals with reliability tests as a reliable method of predicting long-term performance. First test results appear to warrant further pursuit of this program. Present and future testing program outlined. Author

Review: This paper first reviews the bathtub curve and asserts that it probably applies to insulators. The various "stresses" which can cause cumulative damage to the insulator are listed, and an accelerated test is devised by applying peak "stresses" more frequently than they would occur in service. Application of these accelerated tests showed that some kinds of insulators were much inferior to others, and the results appear to be borne out in service. Thus, the accelerated testing program is reasonable, at least in distinguishing good types of insulators from bad types. The attempt to apply the Weibull distribution to the results is not as satisfactory as the author wishes. For example, if several points do lie exactly on the straight line, one is immediately suspicious because if the points do follow the Weibull distribution, one would not expect a very few to lie on a straight line but to have considerable scatter about it. The separating of a small batch of insulators into two different groups on this basis is perhaps even less satisfactory Nevertheless, even without any statistical analysis, the results of the tests are obvious as pointed out by the author. All in all, this paper is an example of the application of accelerated testing to an area with which most aerospace reliability engineers are not familiar.

86 FIELD/CONSUMER ACTIVITY

No abstracts in this issue.

87 MAINTAINABILITY

R70-14905 ASQC 872; 615; 814
THE REPAIR LIMIT REPLACEMENT METHOD
N. A. J. Hastings (Univ. of Birmingham, Dept. of Engineering Production, Birmingham, England) *Operational Research Quarterly,* vol. 20 1969 p 337–349 10 refs

In the repair limit replacement method when an item requires repair it is first inspected and the repair cost is estimated. Repair is only then undertaken if the estimated cost is less than the "repair limit". Dynamic programming methods are used in this paper as a general approach to the problem of determining optimum repair limits. Two problems are formulated and the cases of finite and infinite planning horizons and discounted and undiscounted costs are discussed. Methods are given for allowing for equipment availability and for the introduction of new types of equipment. An improved general formulation for finite time horizon, stochastic, dynamic programming problems is developed. Author

Review: This paper demonstrates the use of dynamic programming methods in the formulation and solution of problems in determining optimum repair limits. Such limits are critical values of repair cost above which it is cheaper (in terms of the total expected cost of maintaining equipment operation) to replace the failed item rather than to repair it. The paper treats problems concerning equipment whose condition is (a) related to age and (b) related to the number of major repairs an item has had. The relationship with previously published work is indicated and the pertinent references are cited. Practical advantages of the method and some features of its implementation are discussed. The mathematics of the paper was not checked in detail; but, on the basis of a spot check, it appears reasonable and there is no basis for doubting its competence. The subject matter of this paper is such that it

will be of interest mainly to the theorist who is concerned with the modelling of maintainability.

R70-14923 ASQC 872; 824
PLANNED REPLACEMENT: SOME THEORY AND ITS APPLICATION
Gerald J. Glasser (New York Univ., School of Business, New York, N.Y.) *Journal of Quality Technology*, vol. 1, no. 2 Apr. 1969 p 110–119 13 refs
(A69-38267)

Application of the probability theory to the problem of preventive maintenance, or replacement theory. Two basic models for replacement planning are described–namely, age replacement and block replacement. Both of these methods assume continuous surveillance and the immediate replacement of operating failures. The cost of periodic inspection to discover failure can be built into either model. The theory as presented applies to cases where there is no substantial uncertainty about the nature of the distribution of times-to-failure and the parameters of this distribution. The models described are applicable to problems in maintaining individual parts or pieces of equipment, or replacing groups of homogeneous parts.
I.A.A.

Review: The title of this paper aptly describes its contents, since it is an excellent introduction to the basic mathematical concepts pertinent to problems of preventive maintenance, together with a good practical discussion of the application of replacement theory. The paper will thus serve a very useful purpose for both the statistician and the engineer who desire such an introduction. The statistical theory which is presented can be assimilated readily by anyone who has a knowledge of basic statistical concepts. The paper provides a concise description of the age replacement model, in which a unit is replaced after it has attained a specified age or earlier if it fails prior to that specified age. The block replacement model, which specifies that all units in a group are replaced periodically, is also described. As the author indicates, these are among the simplest models available for planned replacement. However, he does make reference to other models which are more elaborate, and cites thirteen references in which more details can be found. An extension of these models to which the author does not refer is the consideration of components which are repairable. This introduces the alternative of repairing an item rather than simply replacing it. It is then possible to consider critical values of repair costs below which it is cheaper (in terms of the total expected cost of maintaining equipment operation) to repair the failed item rather than to replace it. One treatment of this topic is found in [1].

Reference: [1] N.A.J. Hastings, "The repair limit replacement method," Operational Research Quarterly, vol. 20, 1969, pp. 337–349.

R70-14935 ASQC 871; 872
Philco-Ford Corp., Palo Alto, Calif. Western Development Lab.
MAINTAINABILITY OF MICROCIRCUIT EQUIPMENT
Harry M. Day and Philip Jordan Mar. 1968 355 p refs
(Contract F30602-67-C-0264)
(AD-842399; RADC-TR-68-187)

The long range impact on maintainability caused by the use of microcircuits in electronic equipment is discussed. The objective is to determine the impact of maintainability with the introduction of microcircuit equipment into the inventory. Three ranges of Mean Time To Rapair /MTTR/ are recommended to aid in determining fault diagnosis and isolation requirements. The Discard At Failure Maintenance /DAFM/ model is revised and simplified to include microcircuit equipment and LSI application. A maintenance concept policy has been developed in draft form for inclusion as an Air Force regulation.
Author

Review: This is a long detailed report, and many parts of it can profitably be skipped by those who are not interested in the details of some of the examples. (This report has only recently had its distribution limitation removed, and thus can now provide to more people the examination of the philosophy of repair.) The procedures for maintaining equipment considerably affect its reliability as well as its availability. The analysis in the report is generally good although the details of Section 2 were not checked. Many of the cost estimates seemed to be linear (they are additive; the costs of many kinds of things are not affected by decisions about other things). One result of the analysis tends to be somewhat discouraging: even though microelectronics can reduce directly the maintenance required, the reduction in people can be insignificant unless a large portion of the equipment on the base is electronic in nature and has been converted to microelectronics. (On page 1-9, the vertical scale on Figure 1-3 is not understandable.)

SUBJECT INDEX

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS VOLUME 10 NUMBER 3

Typical Subject Index Listing

PROBABILITY
Procedures for applying sequential probability ratio tests in analyzing checkout and support equipment
TR-3 c84 R70-12733

SUBJECT TERM | REPORT NUMBER | NOTATION OF CONTENT | CATEGORY NUMBER | *RATR* ACCESSION NUMBER

The Notation of Content, rather than the title, is used to provide a more exact description of the subject matter. The category number and *RATR* accession number are used to locate the abstract-review appearing in the abstract section of *RATR*

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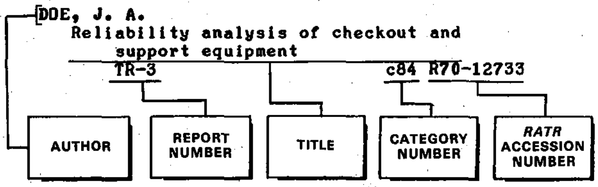
PERSONAL AUTHOR INDEX

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS VOLUME 10 NUMBER 3

Typical Personal Author Index Listing



The category number and the *RATR* accession number are used to locate the abstract-review appearing in the abstract section of *RATR*.

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REPORT AND CODE INDEX

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS VOLUME 10 NUMBER 3

List of Report Numbers

This may be used to identify the *RATR* accession number of reports covered in this journal. To the right of each report number is the *RATR* accession number preceded by the category number for locating the abstract-review in the abstract section of *RATR*. For purposes of this index, AD, N, and A numbers (accession numbers from *TAB, STAR,* and *IAA*, respectively) and ASQC code numbers are treated as "report" numbers. Thus, the section of this index listing ASQC codes may be used to identify the *RATR* accession number of the coded abstract-reviews appearing in *RATR*.

ACCESSION NUMBER INDEX

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Reliability Abstracts and Technical Reviews

APRIL 1970

Volume 10
Number 4

R70-14962—R70-15011

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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The second section of *RATR* contains four indexes: The Subject Index is to assist in scanning or searching the literature on specific topics. The Personal Author Index identifies the publications of specific authors. The Report and Code Index is a listing of the report numbers of items abstracted and reviewed in the journal; this index also includes a listing of the ASQC codes for identifying the *RATR* accession numbers of the items to which the codes have been assigned. The Accession Number Index identifies the categories in which the abstract-reviews appear in the journal. Cumulative indexes are published annually.

EXAMPLES OF CITATIONS IN *RATR*

RATR ACCESSION NUMBER	R70-12733 ASQC 844; 413	ASQC CODES
	General Equipment Company, Banville, Calif.	CORPORATE SOURCE
TITLE	**RELIABILITY ANALYSIS OF CHECKOUT AND SUPPORT EQUIPMENT**	
AUTHOR	John A. Doe 23 Sep. 1969 27 p refs	PUBLICATION DATE
CONTRACT OR GRANT	(Contract NAS15-13411)	*TAB* AND *STAR* ACCESSION NUMBERS
REPORT NUMBER	(AD-629305; N69-15098; TR-3) Avail: CFSTI	SALES AGENCY

RATR ACCESSION NUMBER	R70-12739 ASQC 814	ASQC CODE
TITLE	**SEMICONDUCTOR RELIABILITY**	
	Joseph A. Smith (Eastern University, Arlington, Penn.)	AUTHOR AND AFFILIATION
JOURNAL REFERENCE	*Electric Journal,* vol. 8, Apr. 1969, p 478–492.	
	(A69-12569)	*IAA* ACCESSION NUMBER

RATR ACCESSION NUMBER	R70-12765 ASQC 773; 221; 823	ASQC CODES
TITLE	**TESTS OF SYSTEMS WITH SOME DEPENDENT FAILURES**	
	Joseph A. Smith (Eastern University, Arlington, Penn.) and B. James White (General Equipment Company, Banville, Calif.)	AUTHORS AND AFFILIATIONS
CONFERENCE OR SYMPOSIUM REFERENCE	*Association of Reliability Engineering, Failure Rate Conference, Olney, Tex., Mar. 13–17, 1969,* 8 p. Available from Assoc. of Reliability Eng., New York: $1.00	AVAILABILITY AND PRICE
IAA ACCESSION NUMBER	(A69-12407)	

VOLUME 10 NUMBER 4

Reliability Abstracts and Technical Reviews

A Monthly Publication

of the National Aeronautics and Space Administration

April 1970

80 RELIABILITY

R70-14962 ASQC 802

Air Force Systems Command, Wright-Patterson AFB, Ohio. Foreign Technology Div.

CALCULATING THE RELIABILITY AND EFFICIENCY OF RADIO ELECTRONIC APPARATUS: A HANDBOOK

V. A. Lutskii 14 Nov. 1968 162 p refs Transl. into ENGLISH of the book "Raschet Nadezhnosti I Effekt. Radioelektronnol App." Kiev, Naukova Dumka, 1968 p 1–208

(N69-27100; AD-683581; FTD-HT-23-493-68) Avail: CFSTI

The manual discusses methods of evaluating quantitative indices of reliability of radio and electronic systems and elements, at various rules of time distribution, for trouble-free operation. It presents generalized data tables to help determine equipment reliability indices, taking into account the effect of operating conditions and electric load of the elements, according to the time distribution law of the indices. Particular attention is given to the evaluation of reliability indices (discounting the shift of operation parameters) and error magnitude-effectiveness and mean losses, which become indispensable in investigating the reliability of complex systems. The analysis of reliability-index calculation is illustrated by detailed examples. In conclusion, the methods of increasing the reliability of radioelectronic equipment are discussed and comparative evaluation of such methods given. Author (TAB)

Review: This handbook is much shorter than the one by Kozlov and Ushakov which is also reviewed in this issue of RATR, although the emphasis is still largely on calculation, i.e., mathematical reliability. It tends to have more explanations in it and be somewhat more oriented toward engineering; that is, there is more evaluation of the mathematical models than in the other handbook. In this respect, it is closer to Shooman's book (see R69-14176). The calculations are more elementary than in the Kozlov and Ushakov book, so that one would have little reason to seek this handbook out for his own library. Typical of the kinds of editorial problems that can creep into a work such as this is the fact that the labels are reversed on the two curves shown on page 11. (One is the hazard rate curve giving the bathtub shape, and the other shows the corresponding failure frequency curve.) The last chapter treats engineering methods for improving reliability although unfortunately there is little other than redundancy. The handbook was originally published in 1966 (the CFSTI translation became available in 1969). The text is certainly as good as any English text written around that time or before. (This does not mean that the handbook is of excellent quality but merely that it suffers from the same kinds of problems that any such handbook seems to suffer from.) The author of this book is not as well known as Kozlov and Ushakov, nor does he have a prominent figure giving a foreword to the handbook. The bibliographic citations are of little value to American readers since virtually all of them are Russian works.

R70-14963 ASQC 802

Air Force Systems Command, Wright-Patterson AFB, Ohio. Foreign Technology Div.

A CONCISE HANDBOOK ON RELIABILITY CALCULATIONS FOR RADIOELECTRONIC APPARATUS

B. A. Kozlov and I. A. Ushakov Jul. 1968 308 p refs Transl. into ENGLISH of Kratkii Spravochnik po Raschetu Nadezhnosti Radioelektronnoi App. (Moscow) 1966 p 1– 432

(N69-28324; AD-684671; FTD-HT-23-1669-67) Avail: CFSTI

The handbook presents a brief exposition of the basic premises of reliability theory and methods of calculation and experimental evaluation of various indices. The reliability-calculations handbook is designed for specialists concerned with problems of ensuring reliability in radioelectronic apparatus during its design, manufacture and use. Author (TAB)

Review: This is a handbook rather than a textbook and is concerned largely with mathematical models for calculating system reliability and associated quantities. The closest American book is probably Shooman's "Probabilistic Reliability: An Engineering Approach" (see R69-14176). The formulas were only spot checked, but the mathematics appears to be quite competent. There is a Foreword by Gnedenko, one of the foremost probability/statistical theorists in Russia. His comments are that the book is competent, but he disagrees with some of the organization and emphasis, which, as he says, is more a matter of personal taste and preference than anything else. The book is too terse to be suitable for self-education or a textbook, but it can be quite useful for a reference. There are especially many formulas concerned with redundancy; most are tabulated in an easily-retrievable fashion. The explanations of probability and statistics are good; a few terms may be somewhat confusing to American readers. For example, in Chapter 1, probabilistic definitions are given and contrasted with statistical definitions. The statistical definitions turn out to be estimates made from a finite sample. The chapter on the processing of reliability data deals with curve fitting, estimation, etc., and gives the usual statistical techniques. It is important to remember that the entire emphasis of this book, as indicated by the title, is mathematical. There is no concern with design reviews, engineering approximations, management, etc. Those who can find a full-size reproduction of the text are advised to have it in their libraries. The price is modest enough ($3.00 from CFSTI).

The bibliographic citations are of little value to American readers since they are largely Russian works.

R70-14965 ASQC 801
RELIABILITY DEFINITIONS FOR ELECTRONIC EQUIPMENT
F. Ask *Electronic Engineering,* vol. 42, no. 496 June 1969 p 13–16

Definitions and expressions, most frequently encountered in quantitative reliability analysis, are explained, and the need for international agreement on terminology is stressed. Particular emphasis is placed upon failure rates and mean time between failures (MTBF). Figures are included which depict (1) surviving components as a function of time, (2) failing components as a function of time, (3) failure density as a function of time, (4) failure rate as a function of time, and (5) the relationship between MTBF and the number of components. Author

Review: This is the usual type of elementary introduction to reliability mathematics. It is generally adequate in explaining the terms, although the following points should be noted (in contrast to the statements in the text). (1) Gradual failures cannot always be predicted. Sudden (catastrophic) failures are not always completely unpredictable. (2) The early failure period is unfortunately often of major interest to the user since many manufacturers do not "burn in" their equipment. (3) The + in equation 3 should be an =. (4) The author's failure density is sometimes called the failure rate and the author's failure rate is sometimes called the conditional failure rate or the hazard rate. It is easy to infer from the paper that the author's nomenclature is standard. (5) Contrary to the appearance of the pictures, if the author's failure rate is constant, the author's failure density is not. Also, if there is a burn-in period by the manufacturer, the failure density curve would be renormalized upon delivery (R(0) = 1) and thus is not continuous as shown in the sketch. In a private communication the author has stated that *Electronic Engineering* has promised to issue an erratum.

81 MANAGEMENT OF RELIABILITY FUNCTION

R70-14967 ASQC 810
MACHINE TOOL RELIABILITY
W. T. Truscott *The Quality Engineer,* vol. 33, no. 5 Oct. 1969 p 7–16 5 refs

Reliability problems arising from the introduction of new generation numerically controlled (NC) machine tools are discussed from a user's viewpoint. An approach in terms of managerial objectives is considered essential. This approach recognizes: (1) The potential purchase of equipment must be assessed in terms of all relevant factors such as performance capability, delivery, and price, in addition to reliability. (2) Operational problems of equipment reliability must be considered in relation to the size and nature of other problems affecting production and their relative ease of solution. (3) Operational problems of system unreliability (error generation) throughout the process from drawing creating to metal removal need to be attacked by evaluating the integrity of each system element at the source, rather than by subsequent rejection of the defective product by inspection. Author

Review: This article is of interest to aerospace reliability engineers for the following two reasons. (1) Numerically-controlled (nc) machine tools are now an essential part of the manufacture of much aerospace hardware, and (2) a numerically-controlled machine tool is a large complex device consisting of electronic-mechanical-hydraulic parts similar to the kinds which are found in aerospace vehicles. The article is written from the point of view of a user, and in this regard, is quite temperate (even bending over backwards somewhat) with regard to manufacturers. The author related an anecdote about manufacturers using their customers as guinea pigs on early models of nc machine tools and apparently regarded it as an unfair criticism. It is unfair only in the sense that one may not realize that this is the nature of things: manufacturers have no economic way to perform all the tests on a piece of equipment that will be performed in service. Probably the people who do the greatest disservice to this concept are salesmen and advertising writers who may lead the customer to think that this is not so. It is not a condemnation of manufacturers that they must use their early customers as part of their R&D labs, except insofar as the manufacturer has not used the state of the art in reliability and maintainability engineering in developing his product. Many of these reliability techniques not only can save his customers trouble but can save the manufacturer himself money in the prototype and hardware stages. But it is likewise true that no individual or group of people can conceivably think of all of the details for an extremely complex system without at some time or other trying it out. The author has good practical advice for people who are involved in the purchase of these large systems, although this advice in some ways is limited to the very large purchaser. Small companies may find that the manufacturer pays much less attention to their complaints and suggestions. (Contrary to the author's assertion, it is not necessary to have a confidence level and limit expressed for reliability in order for it to be legally binding, although it may be wise, especially for the manufacturer, to have it there. There are many misprints at the top of page 11.)

R70-14968 ASQC 810; 775; 844
National Academy of Sciences-National Research Council, Washington, D.C.
NONDESTRUCTIVE EVALUATION Final Report, 1967–1969
Jun. 1969 161 p refs
(Contract DA-49-083-OSA-3131)
(N70-10473; AD-692491; NMAB-252) Avail: CFSTI

An analysis considering nonuniform radiosity and assuming diffusely emitting and reflecting surfaces is presented. The shields are planar and circular, while the sources may be surfaces of revolution. The effects of source geometry, number of shields, spacing, and surface properties are discussed. Shield conductivity and selective coatings are investigated. Specularly and diffusely reflecting surfaces are discussed under the simplifying assumption of uniform radiosity. Also, the effects of thermal radiation on the temperatures of a conducting structural member are analyzed. Results are presented showing the effects of significant parameters on the temperature profiles and heat transfer rates. The computer program for the shield analysis is listed. Author

Review: This report will be useful for planners, managers, and those who are interested in furthering the discipline of reliability. It does not contain information for design or analysis. As would be expected from such a panel (selected for both interest and competence in the topic), the discussions of the technical points are good, and the panel feels a sense of national urgency about the situation. If the desires of the panel for promotion and education were to be fulfilled, one would have to be somewhat careful since

you cannot promise anyone a job in this field even if there is a "national need." This is becoming painfully clear to recent Ph.D.'s in physics, chemistry, psychology, etc., where participants in those fields felt there was a national need for more activity and more practitioners. Only it turns out that now the supply is appreciably exceeding the actual demand in terms of open salaried positions. Also, the need for more NDE engineers in research must be put in perspective with other national goals and needs. Nevertheless, this report is a worthwhile endeavor to put NDE in its rightful place among these other goals. Certainly if no one explains and analyzes its urgency, national planners cannot be expected to include it. An important facet of NDE which is touched upon in the report is that in some situations the techniques are so sensitive that evidences of imperfections can be found, but the flaws are so small that they are not harmful in any way. This raises problems especially with specifications which were written earlier and require that the hardware contain no evidence of "defects" detectable by the particular NDE method. In a private communication, a representative of the National Materials Advisory Board has summarized a point very well as follows. "In essence, however, the in-depth study revealed nothing which was new or different to the professional in NDE. The point to be emphasized is increasing reliability. To increase reliability of materials at higher design limits for sophisticated military, aerospace, and industrial systems, NDE must be deliberately incorporated into every phase of their design-production-service cycle."

R70-14969 ASQC 810; 824; 844

Stanford Univ., Calif. Dept. of Statistics.

THE STATUS AND IMPACT OF RELIABILITY METHODOLOGY

Gerald J. Lieberman Jan. 1969 38 p refs Presented at the Res. and Technol. Conf. on Optimization Statistics, Simulation, and Inform. Processing, Washington, D.C., 11–13 Sep. 1968 Sponsored jointly by ONR and George Washington Univ.
(Contract Nonr-225(53))
(N69-20528; AD-681028; TR-115) Avail: CFSTI

The paper presents the current status of reliability methodology, and describes its practical impact. Mathematical models of complex systems are analyzed, together with the combinational probability necessary to calculate the system reliability, or bounds on the system reliability. Component time to failure distributions are studied and lower confidence bounds obtained. Models of underlying physical processes which induce time to failure distributions are also investigated. Author (TAB)

Review: This is a good paper. It is not too long and contains some quite practical advice. The paper may be a little too mathematical for some reliability and design engineers, but those who are familiar with Weibull and similar distributions will not find the mathematics too difficult. The paper is not mathematical per se but discusses the utility of the mathematics. The author has some good comments on estimating the failure rate of equipment by such techniques as MIL-HDBK-217 and also on estimating the distribution from a small sample. For example, he concludes that it is almost impossible to prove that a small sample has not come from a Weibull distribution. The very low power of tests of fit is often overlooked by engineers and amateur statisticians. This is a good tutorial paper and can profitably be read by those involved in the reliability discipline whether from an engineering or theoretical point of view. The approach is both sound and enlightening.

R70-14985 ASQC 810; 821

THE IMPACT OF POLICY ON SYSTEM RELIABILITY

Harald R. Leuba (Department of Defense, Washington, D.C.) *IEEE Transactions on Reliability*, vol. R-18, no. 3 Aug. 1969 p 137–140 3 refs

Examples taken from observations of current military maintenance experience show how reliability is affected by the paperwork and procedures which surround a system's use. Information theory is used as a measuring device to demonstrate the degree to which system performance is not a function of engineering design. In the case studied (the Air Force's F-106 avionics systems in use), many reported failures were not the result of either faulty design or human error, but were rather "required" by the procedural environment. Information theory provides a means of measuring the size of this effect. Furthermore, information theory in this kind of application may be useful in sorting out the relative importance of the various factors which influence variation in system performance. Author

Review: This is an excellent paper on the influence of policy on system reliability. While many people have suspected that the author's conclusions were true, quantitative confirmations are important. Furthermore, the author has expressed them forcibly and clearly so that they are readily understood by anyone with an engineering or administrative background. Even though much more work remains to be done in this area, this paper (and the references upon which it is based) will serve for some time to come as one of the basic references on the topic. Everyone in the reliability business, whether at the administrative or engineering ends, ought to be familiar with the contents of the paper. The results and conclusions can be understood without recourse to any mathematics. Once a person has read the paper, the results are the kind he will be quoting in his discussions with others for some time to come. Hopefully, these results will lead to changes in policy so that the reliability of systems can be increased. Unfortunately, the explanation of the method is not too clear, partly because it is so incomplete. It will be necessary for almost everyone to go back to the original references, in which presumably the method is explained in much more detail. Only a very qualitative, hazy picture can be obtained from the text (unless of course one is already familiar with the detailed methods).

R70-14993 ASQC 815

PAINT FAILURES DUE TO INADEQUATE SPECIFICATIONS

K. A. Chandler (British Steel Corp., London, England) (*Corrosion Symposium, London, 1969, Paper* 3 p) *Methods and Materials*, vol. 16, no. 10 Oct. 1969 p 22–24

Failures due to inadequate specifications are discussed in terms of surface preparation, paint thickness, paint application, and paint systems. As the most serious failures occur on partially weathered steel, it is recommended that blast-cleaning or pickling should be specified to ensure that all rust and scale are removed. To prevent rust after cleaning, the application of a suitable primer should also be specified. The correlation between the thickness and life of a point coating is considered, and it is pointed out that having specified a minimum thickness of paint for each coat it is necessary to specify a method of checking it. Problems arising from paint application are classified as (1) poor maintenance and incorrect operation of the equipment; (2) application of paint under unsatisfactory ambient conditions; and (3) inadequate application of paint at vulnerable features such as welds. In selecting a paint system, data should be obtained on the compatibility of different paints, the minimum standard of surface preparation required, and the effects of factors such as dampness and the types of thinners that should be used. M.G.J.

Review: This paper will be of interest to reliability engineers

for two reasons: (1) many aerospace structures are protected from the corrosive environment by a paint or similar film, and thus an understanding of the process of applying and specifying paint films is worthwhile, and (2) the problem of adequate specifications is valid for many processes and hardware other than paint films. The difficulties in generating a specification which is adequate, but not overly specified, are well brought out as are the various implied contradictions that can be contained in a specification if the writer is not careful. Unfortunately, it is sometimes difficult to write a specification that is not subject to dispute under difficult conditions such as a situation in which one of the parties decides to argue his way out of a hole rather than admitting he is wrong. Thus, writing such an ideal specification may not be as easy as the mere statement of the admonition might imply to the uninitiated. This paper is especially good for the novice in specifications, viz., the person who has not had to write them or buy according to them. Many unsuspected sources of complications are explained.

R70-14998 ASQC 810; 821

SUBSTATION EXPANSION, RELIABILITY, AND TRANSFORMER LOADING POLICY ANALYSIS

W. R. Ossman (The Cleveland Electric Illuminating Company, Cleveland, Ohio), N. H. Woodley (Westinghouse Electric Corp., Pittsburgh, Pa.), and R. H. Miller *IEEE Winter Power Meeting, New York, Jan. 26–31, 1969, Paper* 10 p refs

This is the first known attempt to apply probability methods to the evaluation of sub-station expansion plans and transformer loading policies. The method develops the probabilities of exceeding maximum transformer temperatures and the expected loss of transformer life utilizing local historical substation load and ambient temperature environmental conditions. Alternate substation expansion plans to meet forecast area load are compared on the basis of cost versus reliability. Author

Review: The first part of this paper deals largely with the calculation of various "stresses" on the transformer in the form of ambient temperatures and load requirements. Since the transformer temperature is rarely at steady-state, an iterative procedure is used to find the temperature as a function of time, including the load variations. The Arrhenius behavior is assumed for degradation of the insulation, and there is presumed to be no scatter in transformer life. The calculations and techniques appear reasonable. The latter part of the paper considers the behavior of the substations using the calculations made previously. They show the power of using the reliability discipline and reliability mathematics in this kind of calculation. Using these results, calculations similar to life-cycle costing can be made in order to find the optimum allocation of equipment to substations. The techniques used in this article are straightforward applications of reliability theory along with the knowledge of the detailed performance of the hardware.

R70-15010 ASQC 810; 832

SAFETY ANALYSIS: TOOL OR TRAP?

Charles E. Cornell (Univ. of Southern California, Institute of Aerospace Safety and Management, Los Angeles, Calif.) *Space/Aeronautics,* vol. 52, no. 5 Oct. 1969 p 45–53

(A70-12263)

Consideration of system safety, with emphasis on accident prevention. Some tradeoffs are inevitable, since attempts to control all mission variables or to produce systems involving no risk are impractical. Through careful investigation, accident trends can often be detected, contributory causes isolated and eliminated, and repeat performances of prior accidents prevented. Risks allocation is considered. It is based on a value judgment as to the risk an astronaut, a launch-pad propellant loader, an airline passenger, etc., should accept. The assumption of specification/compliance—namely, that if the parts have a lower cumulative probability of failure than the risk previously allocated for the system, then the requirements have been met and the system is as safe as prescribed—is considered actually to distract from the goal of accident prevention. Contingency-mode analyses are studied, as well as the use of the fault-tree method. It is considered that safety engineers should direct their efforts toward hardware, procedures, training, and other factors that tangibly reduce accidents. I.A.A.

Review: While the author of this paper is concerned with system safety as a discipline, there is much in the paper which will provide worthwhile reading for reliability managers and reliability engineers, especially those who are concerned with the interface between reliability and safety. The paper is written in a smooth style for easy readability, and is well illustrated. It presents a strong case for less emphasis on numerical "verification" of existing design and more emphasis on improving design. With reference to compliance with specified numerics, the author states that "there is inherent danger in any analysis which provides an estimate of a desired system characteristic, then sets out, through subsequent estimates, to validate the original estimate." The importance of the "people problem" is emphasized. Contingency mode analyses are described and illustrated. Also prominently featured is the safety analysis fault-tree, in which the emphasis is on diagnostic questions raised at each critical node, rather than on numerical safety assurance and prediction.

R70-15011 ASQC 810

HOW WE LOOK UPON POWER SYSTEM RELIABILITY

Lev S. Lindorf (All-Union Scientific Research Institute, Moscow, USSR), and Andrei M. Necrasov (State Planning Committee, Electrical Engineering Dept., Moscow, USSR) (*IEEE Industrial and Commercial Power Systems and Electric Space Heating and Air Conditioning Joint Technical Conference, St. Louis, May 7–10, 1968, Paper) IEEE Transactions on Industry and General Applications,* vol. IGA-5, no. 2 Apr. 1969 p 112–120 9 refs

The problem of the reliability of electric supply and operation is a very complex problem involving the generation of electric power, its distribution, and the operation of electric driven mechanisms at power stations and consumers. This paper describes various means used in the U.S.S.R. to improve reliability of power supply and those measures introduced to improve reliability of consumers at short time interruptions of power supply. Due to the growth of generator and motor ratings, new problems in improving reliability arise. Problems in future improvement of reliability are listed. Author

Review: It is occasionally interesting for aerospace engineers to compare their concepts of reliability and their tools for implementing it with those of other engineering groups. It appears that electric power systems and the aerospace industry have much in common with regard to the reliability discipline. The power system people generally look on reliability as an engineering effort rather than a numbers game. They are very concerned about planned maintenance, especially to remove incipient failures. The management of this system, in all of its ramifications, must be provided for very carefully and attention to detail is the basic concern. Very similar things can be said about the aerospace reliability effort. Thus, this paper will be of value for reliability engineers who wish to improve their perspective on the reliability discipline.

82 MATHEMATICAL THEORY OF RELIABILITY

R70-14970 ASQC 821; 431

A PROBABILITY SIMULATION METHOD FOR DETERMINING THE RELIABILITY OF SWITCHING STATIONS

Jiri Sverak (American Electric Power Service Corp., New York, N.Y.) *(IEEE Winter Power Meeting, New York, Jan. 26–31, 1969 Paper) IEEE Transactions on Power Apparatus and Systems,* vol. pas-88, no. 11 Nov. 1969 p 1657–1664 6 refs

A useful treatment of as broad a class of such reliability problems of switching stations and substations as can be treated by the theory of Markov processes is covered. The mechanics of failure and repair effects are discussed by means of mathematical models, and basic members with memory, fluctuating failure, and repair rates are evaluated. The system is assumed to operate under normal and stormy-weather conditions. The nonrandomness of special events are involved. In addition, a Monte Carlo method of computer simulation is presented for determining the reliability of stations. Author

Review: This paper is not too clear, partly because of the language difficulty. If one is familiar with Markov processes and with reliability, he can analyze what the author is driving at. One difficulty in using the Markov process with some kind of memory is that the transition rates from one state to another are not independent of any previous states the system may have been in. Therefore, as the author has shown, if in fact it does make a difference to a component (in its failure behavior) whether it has previously been affected or not, then another state must be introduced. If this is carried very far, there will be an extremely large number of states, and the problem will become too complicated to handle. This paper is of primary concern to those doing theoretical work rather than to design or reliability engineers. Theoreticians will undoubtedly be able to figure out what the paper means, and in the event that they have not considered these possibilities, the paper will be of value to them.

R70-14971 ASQC 824; 433

Wisconsin Univ., Madison. Statistics Dept.

BAYESIAN ANALYSIS OF TIME TRUNCATED SAMPLES

Robert H. Lochner (Marquette Univ., Milwaukee, Wis.), and A. P. Basu (Univ. of Wisconsin, Madison, Wis. and IBM Research Center, Yorktown Heights, N.Y.) May 1969 93 p refs

(TR-201)

A Bayesian approach is described for analyzing data from multiply truncated samples. A grouping procedure is given for tabulating the data, and some basic results for this grouping model are presented. A Dirichlet prior density is assigned to the parameter vector p, and the posterior distribution of p is obtained. Properties of the parameters of the prior distribution are considered, along with the posterior distribution of the reliability function R(t) = 1 −F(t), for fixed t. It is shown that, a posteriori, F(t sub i) is the product of i independent beta variables. A simple approximation to the distribution of F(t sub i) is compared with the exact distribution and is found to be adequate. The posterior predictive distribution of a future sample, based on existing sample data, is derived, and a test for increasing failure rate is proposed. The sensitivity of the distribution of F(t sub i) to variation in the prior parameter is studied. This posterior distribution is found to be reasonably insensitive, with sensitivity to variation in the prior parameters decreasing rapidly as the sample size increases. Author

Review: This paper gives a very good discussion of the application of Bayesian methods to the analysis of multiply-truncated samples. The approach is somewhat between nonparametric and parametric statistics in that a nonparametric problem is reduced to a parametric problem by grouping the data in a certain way. The exposition is quite clear and many of the complex mathematical derivations have been placed in three appendices for easier reading. A basic knowledge of mathematical statistics including Bayesian ideas is prerequisite to a full comprehension of the paper. As the authors have pointed out, there is considerable interest in methods for analyzing life-test data from samples in which not all times-to-failure are observed. Hence, this paper is addressed to a problem of practical importance.

R70-14972 ASQC 824; 551

California Univ., Berkeley. College of Engineering.

COMPARISON OF SEVERAL NONPARAMETRIC ESTIMATORS OF THE FAILURE RATE FUNCTION

Richard E. Barlow (Univ. of Calif., Industrial Engineering and Operations Research Dept., Berkeley, Calif.) and Willem R. Van Zwet (Univ. of Leiden, the Netherlands) Aug. 1969 29 p refs Conf. held at Turino, Italy, June 30–July 4, 1969

(Contract Nonr-3656(18))

(ORC-69-25)

Several nonparametric estimators of the failure rate function, assuming that the true unknown failure rate is increasing, are proposed and their asymptotic, properties compared. Finite sample comparisons are made using Monte Carlo methods. Recommendations are made for the benefit of potential users. Author

Review: This is a good report which should be of interest to all research workers who are applying the recently-developed nonparametric procedures for estimating the failure rate function. Emphasis is on the practical implications of limit theorems proved elsewhere and on small-sample comparisons from simulated samples. Related papers were covered by R68-13835, R69-14681 and R69-14682.

R70-14973 ASQC 824

Boeing Scientific Research Labs., Seattle, Wash. Mathematics Research Lab.

DETERMINING AN APPROXIMATE CONSTANT FAILURE RATE FOR A SYSTEM WHOSE COMPONENTS HAVE CONSTANT FAILURE RATES

J. D. Esary, A. M. Marshall, and F. Proschan Sep. 1969 20 p refs Presented at NATO Reliability Conf., Turin, 1969 *Its* math. note No. 617-A

(N70-14160; AD-695122; D1-82-0898) Avail: CFSTI

It is often necessary to predict the reliability of a system when only the mean lifetimes of its components are known. Questions arise as to when such procedure is precise, and if it is not precise, what constant values for the system failure rate give reasonable approximations for the actual system failure rate function. These questions are answered in the case that components (a) fail independently and (b) have constant failure rates. Author (TAB)

Review: This report presents some useful new bounds and approximations for system hazard functions when the component lifetimes are independent and exponentially distributed. Two numerical examples illustrate the technique for rather simple systems. For complex systems, the computations needed to obtain the bounds might be rather formidable, but the authors do not consider

this aspect of the problem in this report. The interested reader will find directly related papers covered by reviews R67-13094, R69-14679, and R69-14782.

R70-14974 ASQC 824

MEASUREMENT OF RELIABILITY LOSS DUE TO IMPULSIVE NOISE

S. P. Vol'fbein and N. G. Veksler *Telecommunications*, vol. 23, no. 1 1969 p 43–45 6 refs

The probability of loss due to impulsive noise is shown to depend on two statistical parameters of the noise, namely, the mean number of noise pulses per unit time, and the mathematical expectation of the absolute noise intensity. A method for measuring the reliability loss to be expected from impulsive noise is outlined. Author

Review: One of the factors affecting the reliability of a transmission channel is impulse noise. If the noise is large enough, it can cause errors in reading the channel output. These errors depend on the kind of modulation; a table is given in the text to account for different types of modulation. The mathematical development is rather simple and straightforward, and its purpose is to present an approximation that is easily measured. The authors' terminology is somewhat misleading since they show the absolute value of the mean rather than the mean of the absolute values—the words and the notation disagree.

R70-14977 ASQC 825; 614; 838

OPTIMAL SYSTEM RELIABILITY FOR A MIXED SERIES AND PARALLEL STRUCTURE

R. M. Burton and G. T. Howard (U.S. Postgraduate School, Dept. of Operations Analysis, Monterey, Calif.) *Journal of Mathematical Analysis and Applications*, vol. 28, no. 2 Nov. 1969 p 370–382 12 refs

(A70-12995)

Generalization of the optimal redundancy problem. The study considers any mixed series and parallel network consisting of N modules. The ith module has a reliability cost function of ri(di) where di is the investment in module i. The reliability investment functions are not required to be concave or continuous in the dynamic programming model. The objective is to maximize the system reliability subject to cost, weight, or volume constraints. The work differs from others since it permits modules in logical parallel to be of different designs, and investment in a module does not necessarily imply that redundant components will be used. Many previous models have been restricted to the parallel series situation which is a special case of this model. A dynamic programming model is presented for the problem. The application of the generalized decomposition operator is used to develop a set of recursive relations for any mixed series and parallel system of modules. An example and comments on generalizations are included. Author (IAA)

Review: This paper demonstrates the use of dynamic programming to solve mixed series and parallel problems. The problem considered is that of determining the optimal investment in each of N modules to provide the maximum system reliability, subject to a budget constraint. Only one constraint is considered, but the model can be extended to handle multiple constraints. The authors present a concise survey of previous literature in this area, citing twelve references, thus placing their work in perspective relative to the previous publications. The mathematical model and the analysis are described in sufficient detail for those who have prior knowledge of dynamic programming. The applicability of the approach to the reliability design of systems is brought out clearly in an example. This paper will be of interest to theorists concerned with the general redundancy allocation problem. Other papers in this topic area include those covered by R68-14065 (integer linear programming model incorporating multiple restraints), R68-14043 (also applying integer linear programming), R68-14044 (applying convex programming), and R69-14442 (applying geometric programming).

R70-14978 ASQC 824

ELEMENTS OF INFORMATION THEORETIC METHODS: TUTORIAL INTRODUCTION

Thaddeus L. Regulinski (Air Force Institute of Technology, Dept. of Electrical Engineering, Dayton, Ohio) *IEEE Transactions on Reliability*, vol. R-18, no. 3 Aug. 1969 p 82–87 22 refs

The rudiments of information theoretic methods are introduced, and major elements of the communication system are outlined from an information processing point of view. Information is quantified following the work of Shannon. The concepts of uncertainty, self- and mutual information, and entropy are developed as seen at the encoder, channel, and decoder. Channel modeling is demonstrated using a binary symmetric channel as an example. Channel capacity is derived by maximizing transinformation. Elements of coding are described and Shannon's fundamental theorem of discrete noiseless coding is stated. The fundamental relations governing unique decipherability and irreducibility are given and demonstrated by examples. Code efficiency and redundancy are quantified and discussed as system parameters subject to tradeoff. Applications of information theoretic methods in various disciplines are discussed with emphasis on reliability and maintainability. Two unresolved reliability problem areas are identified where, potentially, information theoretic approaches may present a viable solution. Author

Review: This is a good tutorial introduction to information theory. Contrary to the statement in Reader Aids which limits the usefulness of the results to theoreticians, the electrical engineers to whom the journal is addressed will be able to follow the presentation and learn something from it. The concepts of information and entropy as average information are well explained and shown to be plausible. Unfortunately, the typesetting associated with the material in equations (24) through (25) is such that if you did not know the correct formula, you would misinterpret what is written. The correct formula is the following:

$$\sum_{i=1}^{n} D^{-n_i} \leq 1 \qquad (24)$$

The i is a subscript of the exponent n rather than being a multiplying factor. In equation (25), N is put in place of n for the number of message symbols and n is used instead for the number of symbols in a code word (all without explanation). It is not entirely clear how the kind of information theory introduced here is used in reliability. But certainly a knowledge of this material which the author ably presents allows an engineer to ascertain for himself the degree of its application in any one of the subsequent articles in the same issue of the journal. This introduction to information theory is also useful in itself and can be recommended especially to those who are old enough never to have had a course in it in school and who have wondered how some of these concepts arise. The author gives 22 references for further reading in this area.

R70-14979 ASQC 821

THE PRINCIPLE OF MINIMUM INFORMATION

Ralph A. Evans (Research Triangle Institute, Research Triangle Park, N.C.) *IEEE Transactions on Reliability,* vol. R-18, no. 3 Aug. 1969 p 87–90 3 refs

The principle of maximum entropy for assignment of estimated probabilities is intriguing. Since entropy is the negative of information, the principle was renamed. The formalisms for discrete and continuous random variables are described and illustrated. The problem of complete ignorance is discussed and the concept of quasi-ignorance is introduced as a substitute. Constraints on the probabilities, beyond the minimum, are a source of consternation and a stumbling block to the application of the principle. Many questions are raised, but no answers are given. At present, the principle cannot be evoked to solve practical problems in reliability. Theoreticians should apply themselves to find realistic tractable constraints that do not involve logical contradictions. Author

Review: This tutorial paper discusses the assignment of probability mass (discrete variables) and probability density (continuous variables) functions by the principle of minimum information (in the Shannon sense) when there are constraints on the functions other than the necessary ones of non-negativeness and unity sum. This method of determination is potentially useful in cases where one is unwilling to assume a particular form of the mass or density function, but perhaps is willing to assume a value of its mean, variance or some other characteristic. The paper illustrates the discrete and continuous cases with simple examples and discusses in some detail the essential differences in the two cases. The unreconciled difficulty of choosing an arbitrary "measure" function in the continuous case is emphasized. Although the paper is mathematically sound, the philosophical section on *Constraints* will not gain the approval of most statisticians who read the paper. The statements (1) the mean is known and (2) the mean exists would never be confused or used interchangeably by a statistician. They have quite distinct, though related meanings which may be expressed (in the case of continuous variables) as:

(1) $\int x\, f(x)\, dx = \mu$ (a specified number, e.g., .05)

(2) $\int |x|\, f(x)\, dx < \infty$.

Similar expressions apply to the discrete case. Hence, the statement (constraint) "the mean value is known" always has the meaning expressed in (1), never that in (2). There also seems to be the implication in this section that one should not use the minimum information principle if one does not know precisely the value of parameters appearing in the constraints. This again would not get a nod of approval from statisticians. Time and time again statisticians construct decision procedures (e.g., tests of hypotheses, estimators) which are known to have good properties when certain parameters are specified. In practice, the parameters are not known and must be replaced by an estimate. This does not mean the modified procedure is no good. It may have nice properties other than those which are present when the parameters are known. Examples of these modified procedures are the likelihood ratio method of constructing tests of hypotheses in the presence of nuisance parameters and the discriminant function for differentiating between two multivariate normal populations. The "interesting theorem on constraints" which appears at the end of the section is nothing more than an application of the result in calculus which states:

If $R_*^n \subset R^n$ are spaces over which a function $f(\underline{x})$ is defined and if $\underline{x}_0$ is such that

$$f(\underline{x}_0) = \sup_{\underline{x} \in R^n} f(\underline{x})$$

and

$$\underline{x}_0 \in R_*^n$$

then

$$f(\underline{x}_0) = \sup_{\underline{x} \in R_*^n} f(x)$$

It does not matter what type of constraints define R_*^n and R_*^n as long as the constraints are consistent. On the whole this paper should be of value to persons who want an introduction to the principle of minimal information and the problems which arise in its use. Engineers with a knowledge of elementary probability theory and calculus should have no trouble understanding the equations and examples which appear in the article.

R70-14982 ASQC 821

OPTIMIZATION PROCEDURE FOR THE ANALYSIS OF COHERENT STRUCTURES

Lawrence D. Bodin (International Business Machines Corp., New York Scientific Center, New York, N.Y.) *IEEE Transactions on Reliability,* vol. R-18, no. 3 Aug. 1969 p 118–126 10 refs (Contract Nonr-3656(18); DA-31-124-ARO-D-331)

The determination of the reliability level at which to manufacture the components of a coherent structure so that the system reliability is at a certain level and the overall system cost is minimized is considered. Since for most coherent structures the constraint set defines a nonconvex set, any mathematical programming procedure blindly applied to the program converges to a local optimum rather than a global optimum. However, in certain cases, the global optimum can be found for the series and parallel (SP) type of systems. The key to the solution is to optimize each module separately and then to substitute a component for each module where the cost function for the component is the value of the objective function for the module. Author

Review: This theoretical paper consists largely of the statement of the problem, a series of proofs of theorems, and statements of algorithms for solving the problem. As suggested in the reader aids for the paper, the results are useful only to theoreticians; they are not in a form suitable for use by reliability or design engineers. Not all the mathematics was checked, but the problem appears to be well formulated and the mathematics to be competent. The author defines coherent structures in his introduction, so that a previous acquaintance with them is not necessary. Coherent structures are a formalization of assumptions often made by reliability engineers in their work, so that the paper does treat a reasonably practical situation. It is not clear in what way the paper contributes to an information theoretical approach to reliability (the subject of the special issue), but the paper is a worthwhile contribution in its own right to the general theory of reliability.

R70-14983 ASQC 824; 433

KALMAN FILTERING AND ITS APPLICATION TO RELIABILITY

Arthur M. Breipohl (Oklahoma State Univ., Dept. of Electrical Engineering, Stillwater, Okla.) *IEEE Transactions on Reliability,* vol. R-18, no. 3 Aug. 1969 p 127–130 15 refs

The basic ideas of Kalman recursive filtering is explained in such a manner that the application of these ideas to reliability may be seen. The Bayesian viewpoint is adopted, and the explanation of Kalman filtering is broken into two parts: 1) the combination of an old estimate with data, and 2) the updating of estimates via the system model. Author

Review: This is a good introduction to Kalman filtering. It illustrates the basic concepts by means of several examples, but does not get too involved with the various ramifications that Kalman filtering can have. Several good references are mentioned for those who wish to delve into the subject more deeply. There is little if anything in this paper that will have to be unlearned as one becomes more deeply involved in Kalman filtering. (This is an important, sometimes overlooked property of elementary introductory papers since many of them oversimplify to such an extent that wrong notions are introduced.) Some statistical sophistication, especially a familiarity with Bayes' rule, will be necessary in order to understand the paper readily. If one does have this familiarity with statistics, the paper is quite easy to read and straightforward. Without it, the going will be rough. It is not immediately clear what the connection is between Kalman filtering and information theory (concerning the paper's inclusion in this special issue), but this in no wise affects the good utility of the paper.

R70-14984 ASQC 824

AN ESTIMATE OF THE LENGTH OF DIAGNOSTICS TESTS

Franco P. Preparata (Univ. of Illinois, Urbana, Ill.) *IEEE Transactions on Reliability,* vol. R-18, no. 3 Aug. 1969 p 131–136 8 refs

(Contract DAAB07-67-C-0199)

The diagnosis of digital systems can be conveniently modelled as the recognition of distinct binary error-free patterns. Specifically, if for a given fault condition, the pass or fail responses to a set of applied tests are recorded as a column of a matrix M, a test schedule of length k is a subset of the rows of M which preserves column distinguishability. Since the determination of a minimal test schedule is a formidable problem for moderately complex networks, it appears desirable to have guidlines for the evaluation of heuristically or suboptimally computed test schedules. One such guideline is the median $\overline{k_{min}}$ of the minimal test schedule k_{min} over the set of all binary matrices M: while in general $[\log_2 m] \leq k_{min} \leq m-1$, this paper shows that $\overline{k_{min}} < [2 \log_2 m]$, that is, for most practical cases, $\overline{k_{min}}$ is much closer to the lower bound $[\log_2 m]$ than to the upper bound $(n-1)$. Author

Review: This paper presents an interesting result concerning the length of diagnostic tests for digital systems which should be of interest to both theoreticians and designers of digital systems. The paper is well organized and constitutes a definite contribution to the state-of-the-art. Several papers have been concerned with means of generating minimal or nearly minimal diagnostic tests; the author does not treat this problem but gives statistical insight into the length of a diagnostic test by driving the median of the minimal test schedules for a given fault test table. His basic assumption is that the fault test table is a random matrix. All assumptions are noted and the accuracy of the results is qualified. Although the results do present designers with a means of estimating the length of a diagnostic test from the fault test table, there is no procedure for determining how close to the computed median the minimum length diagnostic test might be for a given practical case.

R70-14987 ASQC 822

A NEW FAMILY OF LIFE DISTRIBUTIONS

Z. W. Birnbaum (Univ. of Washington, Seattle, Wash.) and S. C. Saunders (Boeing Scientific Research Laboratories, Seattle, Wash.) *Journal of Applied Probability,* vol. 6, no. 2 Aug. 1969 p 319–327 9 refs

A new two parameter family of life length distributions is presented which is derived from a model for fatigue. This derivation follows from considerations of renewal theory for the number of cycles needed to force a fatigue crack extension to exceed a critical value. Some closure properties of this family are given and some comparisons made with other families such as the log-normal which have been previously used in fatigue studies. Author

Review: This is a later, somewhat revised, version of the report covered by R68-14149. Much of it is copied verbatim, but other parts are added and deleted.

R70-14988 ASQC 824

ESTIMATION FOR A FAMILY OF LIFE DISTRIBUTIONS WITH APPLICATIONS TO FATIGUE

Z. W. Birnbaum (Univ. of Washington, Seattle, Wash.) and S. C. Saunders (Boeing Scientific Research Laboratories, Seattle, Wash.) *Journal of Applied Probability,* vol. 6, no. 2 Aug. 1969 p 328–347 6 refs

The estimation problem is studied for a new two-parameter family of life length distributions which has been previously derived from a model of fatigue crack growth. Maximum likelihood estimates of both parameters are obtained and iterative computing procedures are given and examined. A simple estimate of the median life is exhibited, shown to be consistent and then compared, favorably, with the maximum likelihood estimate. More important, the asymptotic distribution of this estimate is shown to be within the same class of distributions as the observations themselves. This model, and these estimation procedures, are tried by fitting this distribution to several extensive sets of fatigue data and then some comparisons of practical significance are made. Author

Review: This paper is the same as the report covered by R69-14607.

R70-14989 ASQC 824; 822

PROGRESSIVELY CENSORED SAMPLES FROM LOG-NORMAL AND LOGISTIC DISTRIBUTIONS

A. V. Gajjar and C. G. Khatri (Gujarat University, Ahmedabad-9, India) *Technometrics,* vol. 11, no. 4 Nov. 1969 p 793–803

Maximum likelihood estimates of the parameters involved in each stage of censoring are obtained for log-normal and logistic distributions. It is noted that, due to different parameters at different stages, the parameters are estimated from truncated censored distributions. A numerical example is included which gives data on the lives in hours in a random sample of 340 items taken for inspection from a population in which the logarithmic values of the observations are normally distributed. M.G.J.

Review: This paper consists of competent mathematical discussion of the estimation problem for the cases indicated in the title, accompanied by a numerical example. Relevant references are cited. It makes a worthwhile contribution to methods of statistical estimation of reliability. Progressively censored samples arise, for example, when certain specimens must be withdrawn from a life test prior to failure for use as test objects in related

experimentation. They may also result from a compromise between the need for more rapid testing and the desire to include at least some extreme life spans in the sample data. When test facilities are limited and when prolonged tests are expensive, the early censoring of a substantial number of sample specimens frees facilities for other tests, while specimens which are allowed to continue on test until subsequent failure provide an observation of extreme sample values. The mathematical results obtained in this paper are applicable to this type of test situation when the underlying distribution of time-to-failure is either log-*normal* or logistic. The maximum likelihood estimators for the parameters of the *normal* and exponential distributions in this type of testing were obtained by Cohen in the paper covered by R64-11571. Cohen had assumed that the parameters remain the same at each stage of censoring, but in the present paper, the authors assume that the parameters of the distribution under consideration may change at each stage; for example, the remaining items at each stage are checked and the defects are eliminated whenever possible. This means that the authors are dealing with censored samples from truncated distributions. This presumably is what is meant at the end of Section 1 in the paper where the authors refer to estimating "the parameters from truncated censored distributions."

R70-14990 ASQC 824; 822

TWO SAMPLE TESTS IN THE WEIBULL DISTRIBUTION

Darrel R. Thoman and Lee J. Bain (Univ. of Missouri, Rolla, Mo.) *Technometrics*, vol. 11, no. 4 Nov. 1969 p 805–815 4 refs

A test based on maximum likelihood estimators is given for testing the equality of the shape parameters in two Weibull distributions with the scale parameters unknown. Tests for the equality of the scale parameters are also presented along with a procedure for selecting the Weibull process with the larger mean life. Author

Review: This paper is essentially a follow-on to a paper by the same authors and an associate which appeared in the August 1969 issue of *Technometrics* (see R70-14854). The earlier paper was an extensive treatment of estimation for the Weibull distribution. This paper, which uses some of those results, is concerned with testing the equality of the shape parameters in two Weibull distributions with scale parameters unknown, testing for the equality of the scale parameters, and discriminating between two Weibull processes. Together, these papers make a worthwhile contribution to reliability theory, since the Weibull distribution is of quite common occurrence in reliability data. It will therefore be of interest to those concerned with the analysis of Weibull data, as well as to the reliability theorist.

R70-14991 ASQC 821; 831

COMPARISON OF ELECTRIC SUB-STATIONS FROM THE RELIABILITY POINT OF VIEW

S. S. Pingle (Technical Univ., Dept. of Electrical Power Engineering, Budapest, Hungary) *Electrical Engineering*, vol. 4 1968 p 378–387

The reliability calculations pertaining to electric sub-stations is dealt with. As it is very difficult to consider a whole sub-station for general comparison purposes, only one set of incoming and outgoing line has been considered. Detailed calculations have been performed for such ways and reliability formulae for different types of sub-stations have been derived. Cost factor has also been taken into consideration and it has been proved that a good quality circuit-breaker with high reliability would permit us to use a simpler scheme at less cost and at the same time giving high reliability for the scheme as a whole. Thus considerable economy can be achieved by using a costly but highly reliable circuit-breaker. Boolean algebra has been used for the calculations. Author

Review: This paper illustrates the application of Boolean algebra in the analysis of a simple network. Cost factors are taken into account and it is shown in this particular case that it is cost-effective to use an expensive but highly reliable circuit-breaker. While the specific application in this paper is to electric sub-stations, an analysis of this type clearly is applicable to other types of networks as well. Thus, the paper will be of value to those who are interested in a detailed description of the application of Boolean algebra to the analysis of a network.

R70-14992 ASQC 824; 838

DETERMINING THE MEAN TIME TO FAILURE FOR CERTAIN REDUNDANT SYSTEMS

Philip Jumonville and William G. Lesso (Univ. of Texas, Tex.) *ALLE Transactions*, vol. 1, no. 1 Mar. 1969 p 81–82 2 refs

A relatively simple relationship is presented for determining the mean time to failure for systems with redundancy of the type where r out of n units must be operating for the system to be operating. The special case is for units that have constant failure rates. Author

Review: This short technical note presents a result which is well known in the field of reliability engineering but perhaps is not well known to industrial engineers. An important assumption on which the derivation is based is that the failures of the redundant units must be statistically independent. This should always be stated explicitly since it is so important. If the units are statistically independent, then the failure behavior of the live units is in no way affected by the number of failed ones. There are many situations in which this will not be true. Implicit in the discussion is the assumption that the mean-time-between-failures is a useful figure of merit for systems. While it is useful for some systems, other figures of merit are often more useful (such as the hazard rate for times short compared to the MTBF of an element). The derivation also presumes that there is no maintenance or repair at any time. Thus, this article treats a mathematical model correctly. If the mathematical model is applicable, then the formulas in the paper will be useful.

R70-14997 ASQC 824

THEORETICAL RELIABILITY OF THE PARTIAL CHANNEL OF AN FSK OR PSK SSB RADIO LINK

Yu. F. Pelegov, B. A. Klyzhenko, and A. V. Gapich *Telecommunications*, vol. 23, no. 1 1969 p 8–16 7 refs

A method for estimating the digital data transmission reliability over the partial channel of an SSB multichannel radio link is described, for the case of optimal incoherent FSK or PSK reception in a Rayleigh-fading channel. Experimental results are also quoted. Author

Review: As indicated in the title of the paper, this is a theoretical derivation. It is concerned not with hardware reliability as such but with the reliability of message reception due to fading, noise, and other disturbances. The mathematics was only spot checked, but it appears to be competent. The authors do give some experimental results which are not inconsistent with the theory, although there is a factor of 10 spread in the results (so it is not clear that this theory is better than any other in predicting order of magnitude results). The authors' main point is that "if the reliability curves for frequency-shift-keying telegraphy over a route

are known, a simple conversion can be used for a first approximation to the reliability of the partial channel of a single-side-band link." Reliability engineers traditionally have paid much more attention to hardware than to the problems of noise in the transmission medium, but bad reception has the same effect regardless of whether it is due to hardware or to a poor channel. Thus, this paper is a contribution to improving reliability of communications systems.

R70-14999 ASQC 824; 531; 844

CORRELATION AND EXTRAPOLATION OF CREEP-RUPTURE DATA OF SEVERAL STEELS AND SUPERALLOYS USING TIME-TEMPERATURE PARAMETERS

Robert M. Goldhoff and G. J. Hahn (General Electric Co., Schenectady, N.Y.) *The 1968 Materials Engineering Exposition and Congress, Detroit, Oct. 14-17, 1968, Paper* 46 p refs

Seven sets of long-time high-temperature creep to rupture data are presented. Time to rupture, time to 1% creep, and minimum creep rate data are analyzed using various forms of five parametric techniques. A brief description of the origin of the methods is given and then the statistical evaluations of the fit of the original data and of extrapolated values are described and presented. The results of these analyses are tabulated and discussed with particular reference to comparison of methods and alloys among the parameters studied. Metallurgical studies are presented in brief. Author

Review: The authors have performed a service for the engineering and metallurgical community by making these comparisons of several time-temperature relationships as applied to many aerospace alloys. Workers in this field, both designers and theoreticians, will find the paper of use. One thing that is often desirable in statistical work is to give an estimate of the statistical uncertainty involved in the various predictions. In the present case, this would involve stating what the uncertainties were in the values of the parameters for the several equations. If this were done (and perhaps other appropriate statistical information were given), one could calculate the statistical uncertainty in the extrapolated value; that is, granted that the mathematical model is correct, what is the uncertainty in the extrapolated value due to the scatter in the data? It also helps if one states the mathematical model for the uncertainty in the data. In this paper, apparently the log(time)'s are assumed to be identically distributed at all temperatures for any particular model. There is no indication of how accurate this assumption is. The authors do make passing reference to an internal report and perhaps much of this kind of information is in that and was eliminated from this published report in the interest of brevity. The first author in a private communication has stated that the tabular material was held to a minimum and was restricted to that which was both highly relevant and easy to explain to engineers. Both of these criteria are quite commendable. Workers in the field will find this paper, especially many of the compilations of data, of value.

R70-15006 ASQC 824; 431

UNIFORMLY MINIMUM VARIANCE UNBIASED ESTIMATES OF OPERATIONAL READINESS AND RELIABILITY IN A TWO-STATE SYSTEM

M. Mazumdar (Westinghouse Electric Corp., Research Labs., Pittsburgh, Pa.) *Naval Research Logistics Quarterly,* vol. 16, no. 2 June 1969 p 199–206 2 refs

This paper obtains the uniformly minimum variance unbiased estimates of two indices of performance of a system which alternates between two states "up" or "down" in accordance with a Markov process. The two indices are (1) operational readiness, which measures the probability that the system will be up when needed; and (2) operational reliability, which measures the probability that the system will be up during the entire time of need. For the purpose of obtaining these estimates, two types of observations are considered: (a) those which reveal only the state of system at isolated time-points, and (b) those which continuously record the duration of the "up" and "down" times of the system. Author

Review: In this paper, the author uses sampling procedures described in an earlier paper (see R68-13552) to obtain the estimates named in the title. The system model and the sampling procedure are described briefly, and the results are given. Those who desire details on the estimation problem will need to refer to the author's earlier paper. Like the earlier paper, this one consists of clearly presented, competent mathematical work. It will be of value to statisticians who are designing (or helping to design) sampling plans for reliability analysis purposes.

R70-15009 ASQC 824

System Development Corp., Santa Monica, Calif.

ON BETA-MODAL INTERVALS SCIENTIFIC INTERIM REPORT

V. K. Murthy and B. P. Lientz Mar. 1969 28 p refs
(Contract F33615-67-C-1865)
(N69-39551; AD-689826; SDC-SP-3252; ARL-69-0053)
Avail: CFSTI

Beta-modal intervals are important as an indication of concentration of mass. Applications can be found in reliability theory and in certain areas of operations research such as traffic flow, where one seeks estimates on regions of high mortality of components or the location of regions of peak flow, respectively. Estimates for the mode of density obtained by Chernoff, Parzen, and Venter are not applicable in many cases since the mode itself might be the result of a momentary aberration in the physical behavior of a system. Author (TAB)

Review: This is a concise and competent mathematical report which makes a contribution to reliability theory. The β-modal interval is a window about a point x so that the distribution function rises by an amount β over the window. Thus, it is useful in estimating points at which concentrations of mass in the distribution occur. In the context of reliability, these concentrations of mass would represent, for example, regions of high mortality of components. The modal interval is preferable to the single mode since the latter can occur as a result of some spurious activity in the physical behavior of the system represented by the distribution. The distributions considered are the uniform, the normal, and the exponential, of which the latter is of the most direct interest to reliability theorists because of its frequency of occurrence in reliability work. Because of its mathematical nature, this paper will be of interest to the theorist rather than to the reliability engineer. Five references are cited, serving to put the work in perspective relative to previous publications.

83 DESIGN

R70-14966 ASQC 838
IMPROVING RELIABILITY OF AMPLIFIERS BY REDUNDANCY
J. Van Staalduinen *Electronic Engineering,* vol. 42, no. 496 June 1969 p 17–21 2 refs

Reliability and circuit redundancy are discussed, with emphasis placed on ways to introduce redundant transistors into amplifier circuits. The relative advantages and disadvantages of several circuit designs are assessed, and redundant forms of transistors are depicted. Two methods are proposed to improve the reliability of a two-stage amplifier, and formulas are given to calculate the improvement. M.G.J.

Review: This paper shows a design possibility–one which could be analyzed in detail to see how much the reliability of this system was actually improved. One needs to take into consideration such other factors as total heat dissipation, total load on the power supply, and relative probabilities of occurrence of the several failure modes in a transistor. Several things about the paper are not clear. For example, (1) In Figure 1(b), this is not the best form for quadding a resistor when the probability of shorting is greater than the probability of opening. In the author's case, where he has assumed the only failures are short circuits, the shorting bar should be removed. In fact, since he has assumed that the probability of an open is zero, one should not quad the four resistors at all, but should put them all in series. (The only purpose of paralleling is to protect against open circuits. But the figure does illustrate how the resistance will change due to failures. (2) Assumption 2 on the first page is not clear. Since the quadded resistors (there is a shorting bar across the middle) can fail only by shorting, any one failure will cut the resistance from R to R/2, which is outside the allowed range. Thus the author's equation for Pr(success), P_b, is wrong. It should be P_x^4. The equation is the right one for a different set of assumptions. (3) In actual practice, the most common failure mode of resistors is open circuiting rather than short circuiting, so that the best arrangement for protection is to put the resistors in parallel. (4) The author has later pointed out that in the Dutch notation for resistance values, the k (for 1000) goes in place of the decimal point, rather than after the entire number, as is the U.S. custom. (5) It is not clear why some resistors are paralleled and some are not. The author has later said that this was for resistance adjustment (and thus, by implication, not for reliability). The circuit diagrams contain other misprints; in particular, some dots showing interconnection are where they should not be and some are not where they should be. All in all, one should be extremely careful in using this paper for tutorial purposes except by those who are very well acquainted with the entire field of reliability analysis.

R70-14980 ASQC 838; 821
ALGEBRAIC CODING AND DIGITAL REDUNDANCY
Jack K. Wolf, Martin L. Shooman, and Robert R. Boorsty (Polytechnic Institute of Brooklyn, Dept. of Electrical Engineering, Brooklyn, N.Y.) *IEEE Transactions on Reliability,* vol. R-18, no. 3 Aug. 1969 p 91–107 14 refs
(Contract AF-49(638)1600; AF-49(638)1402)

The techniques of coding theory are used to improve the reliability of digital devices. Redundancy is added to the device by the addition of extra digits which are independently computed from the input digits. A decoding device examines the original outputs along with the redundant outputs. The decoder may correct any errors it detects, not correct but locate the defective logic gate or subsystem, or only issue a general error warning. Majority voting and parity bit checking are introduced, and computations are made for several binary addition circuits. A detailed summary of coding theory is presented. This includes a discussion of algebraic codes, binary group codes, nonbinary linear codes, and error locating codes. Author

Review: This is a well-organized tutorial paper which should be of interest to those engineers who wish to obtain some basic concepts in information redundancy. The paper appears to have two major concerns: (1) the theory and application of coding techniques to digital systems with the objective of reducing the probability of an undetected error while not incurring prohibitive hardware penalties, and (2) a review of several types of error correcting codes and a comparison of their usefulness. The application of parity checks and majority voting to several binary addition circuits is clearly illustrated. Sample calculations of the resulting reliability and the probability of an undetected error for the redundant circuit configurations under consideration are explained in sufficient detail to be of use to the reader. A good deal of emphasis is given to majority voting; the authors might have pointed out that this is most often considered as a hardware redundancy technique rather than a coding technique. Although no new material is presented, design engineers might make use of the authors' techniques in making a similar analysis.

R70-14981 ASQC 830
APPLICATION OF ERROR-CORRECTING CODES IN COMPUTER RELIABILITY STUDIES
Mu-Yue Hsiao (International Business Machines Corp., Systems Development Div., Poughkeepsie, N.Y.) and Julius T. Tou (Univ. of Florida, Dept. of Electrical Engineering, Gainesville, Fla.) *IEEE Transactions on Reliability,* vol. R-18, no. 3 Aug. 1969 p 108–118 58 refs

The use of error-correcting codes as one of the important techniques to increase computer system reliability is introduced. The different codes used in the central processing unit (CPU) are described. Since the CPU usually contains the data path, logic, and arithmetic units, the codes used in this area are error-detecting codes, such as parity check codes and residue codes. The codes used or suggested for the memory system are discussed, emphasis being placed on parity check codes, two-dimensional codes, Hamming codes and other recently developed codes. The various codes used in the input/output system are presented. The input/output area of the computer system is relatively unreliable as compared with CPU or memory; therefore, error-correcting codes used in this area usually are much more powerful than single parity check codes. These include codes for the magnetic tape, disk, and drum units. The error coding techniques are compared with other techniques for increasing computer system reliability. The future trend of using error-correcting codes in a computer system is also discussed. Author

Review: This is a tutorial paper which performs that function well for reliability and design engineers. The authors have limited their purposes well and explained them clearly so that there is no misunderstanding on the part of the reader about what the paper is intended to do. Those with only a modest background in coding will have to spend considerable time on the paper in order to understand it. The use of jargon is kept to a minimum, thus greatly improving the tutorial function of the paper. There are 58 references for further study which keeps the tutorial quality at a high level. The text itself is good. It begins at a level where competent engineers without a background in coding can follow the material and it goes on from there. Most engineers, after reading the paper, will feel they have gotten a greater insight into the area than they originally had.

R70-14994 ASQC 831

MARGIN TEST LENGTHENS PUMP LIFE

T. R. Chamberlain and J. H. Ferguson, Jr. (Bendix Corp., Fluid Power Div., Utica, N.Y.) *Hydraulics and Pneumatics,* vol. 22, no. 10 1969 p 120–121

Details are given on a margin test program which was developed to evaluate major design improvements in a turbojet engine, hydraulic nozzle control pump. The test is defined as an accelerated bench test run at overrated conditions that duplicates, in a short time, wear or failure noted in field units only after long periods of service. The test is not intended as a substitute for normal qualification or reliability testing. It was statistically determined that to extend the overhaul period of the pump from 1200 to 3000 hours, with in-production units having a mean time-to-failure of 9.5 hours, the improved units must operate without failure for 30 hours. The specific design improvements added to the pump to achieve the 3000 hours between overhauls are listed. M.G.J.

Review: Accelerated testing is used by many for product improvement, and this paper gives an example of this type of application. The severity level is increased by (1) increasing the "stresses" but not so high that the failure modes and mechanisms are changed and (2) making the operationally severe "stresses" occur much more frequently than in usual operation. The paper describes the procedures and lists some of the changes that were made in these pumps. The paper is useful as an example of intelligent accelerated testing and the benefits that can be derived therefrom. (Accelerated testing, of course, can be misused, and such misuses should be guarded against.)

R70-14996 ASQC 838; 883

DESIGNING FOR RELIABILITY IN AN AUTOMATIC MESSAGE-PROCESSING SYSTEM

Yasuo Fukata, Yasuo Koseki, Seiichi Inoue, Yukio Nakagome (K.D.D. Co., Ltd., Tokyo, Japan), and Hajime Enomoto (Tokyo Institute of Technology, Tokyo, Japan) *Electronics and Communications in Japan,* vol. 52-A, no. 1 1969 p 8–16 16 refs

General reliability design is discussed from the viewpoint of the damage magnitude concept resulting from a system failure, with particular reference to techniques for reliability improvements in automatic message processing systems for international traffic. For dual unsynchronized parallel-operated systems, both message-unit synchronization and character-unit synchronization techniques are considered. For monitoring systems, consideration is given to the system monitoring equipment, control of the system operating mode, information comparison, centralized monitoring of system failure, and to the use of test messages to effect reliability improvement. Operating results of a trial automatic message processing system built to verify these reliability techniques are described. Author

Review: This paper gives the practical design considerations for incorporating redundancy into a message processing system. It also considers self-test aspects of the system. The authors quite properly point out that incorporating parallel redundancy is not just a simple matter of having duplicate equipments available. But rather it completely affects the design and operation of the whole system. The paper is devoted to this kind of design consideration rather than failure rates of the particular parts. The paper is good and can be useful to many designers (although those who have been involved with similar systems may find that they are familiar with the material). For a given time duration of checking, the authors show that there is an optimum interval at which one should check in order to have maximum availability in the system. Their curves, however, show that the check interval has a very broad maximum on the right. Therefore, other considerations that were not involved in the model may suggest a longer check interval even though the calculated availability is reduced somewhat. The authors rightly point out that not all failures are catastrophes and have used a means of weighting a failure according to its bad effects. This allows one to make more intelligent engineering trade-offs concerning the effort to be put into various portions of the system. This is a good paper on this subject, and people who are involved with automatic message systems will be able to understand it and probably profit from reading it.

R70-15002 ASQC 835; 782

PACKAGING AND COOLING PROBLEMS ASSOCIATED WITH MICROELECTRONICS EQUIPMENT

F. Honnor and M. A. Thomas (English Electric Company Ltd., Mechanical Engineering Lab., Whetstone, Leicester, England) *Microelectronics and Reliability,* vol. 8, no. 4 Nov. 1969 p 331–337 6 refs

(A70-12847)

Review of the current status of development of new packaging techniques for electronic equipment, with particular reference to techniques involving high chip density as a means of utilizing the high speed of the oncoming generation of semiconductor devices. The problem of excessive heat generation and its ultimate dissipation, associated with this development, is also studied in terms of the need to transmit the heat from its generation source at the junction to some external sink, and to accurately predict the temperature levels at critical points in the system. The current status of the cooling art is examined, and future cooling techniques that may be employed are discussed. I.A.A.

Review: This paper first discusses the need for efficient removal of heat from high-density packages. Next, it discusses the means of analyzing the heat flow and resultant temperatures. Finally it mentions the several methods often used for removing the heat. The paper is a rather general one. It is easy to infer that none of the methods for thermal analysis are satisfactory—although the reader must remember that some thermal analysis even of the quick-and-dirty type is much better than none at all (see R70-14872). This is a general tutorial paper rather than a detailed discussion of any single point. It is a reasonable paper, perhaps somewhat overly pessimistic with regard to thermal analysis, but will be satisfactory for anyone who needs that kind of message.

R70-15004 ASQC 833

MATERIALS SYSTEMS: A CHARACTER ANALYSIS

William M. Duke (Whittaker Corp., Los Angeles, Calif.) *Metal Progress,* vol. 97, no. 1 Jan. 1970 p 80–85

The systems approach to materials is discussed, and a character analysis is proposed based on the interrelationships between properties, materials, and processes. Character is defined by the following parameters: chemistry; crystal structure; electronic structure; substructure, including point defects, linear defects, planar defects, molecular weight, orientation, and degree of crystallinity; grain size and orientation; porosity, considering volume fraction, size, and distribution; additional condensed phases, such as volume fraction, size, and distribution; grain boundary impurities; solid solution; and surface. Tabulated data give examples of character analyses of a variety of materials, engineering properties, and production processes. It is pointed out that, in the systems-oriented approach, consideration must also be given to part shape, service environment, application, and cost. M.G.J.

Review: Design and reliability engineers are vitally concerned with both the materials and the attention to detail that is necessary in selecting those materials. This article gives a systems approach to the problem. The systems approach has its adherents and its detractors, and is the butt of many jokes. This paper gives as good a description of the systems approach applied to materials as one will find; it will be of interest to reliability and design engineers for that reason. In many industries, the use of a new material must come up through a development/new-product section rather than a designer's being able to specify it on a production part without the company's having had experience with it. Many people, of course, have been applying this kind of systems approach without knowing it was called that, and they have been doing it for many years. Witness the various forms in which metal may be processed, the substitution of plastics for metal (and vice versa). The thing that is not brought out in this article is the set of practical constraints under which many designers operate. If their company is traditionally a metals fabricating one (by punching, machining, heat treating, etc.), introducing powder-metal or plastics is more difficult than just deciding that these alternate materials have all the desired mechanical characteristics. There are the problems of capital investment; familiarity of production-line workers, foremen, purchasing agents, engineers with the material; there is also usually the ever-present realization that the characteristics we engineers assign to materials are far too few and too approximate to indicate the difficulties one will get into by switching to it. It is important that at least some group in each company or plant be charged with the responsibility for constantly surveying the materials field and experimenting with new materials and fabrication techniques that appear to have the desirable properties. The idea of filing the materials information by certain kinds of properties, design techniques, processing methods, etc. is a good one. It seems to be an application for computers, as the author suggests. The computer in this case might also be programmed to ask the detailed questions to which the reliability and design engineer needs answers when designing a part.

R70-15008 ASQC 838; 825

OPTIMAL REDUNDANCY FOR RELIABILITY IN SERIES SYSTEMS

P. M. Ghare and R. E. Taylor (Virginia Polytechnic Institute, Blacksburg, Va.) *Operations Research*, vol. 17 Oct. 1969 p 838–847 11 refs
(A70-11383)

Development of a new procedure for determining the optimal number of redundant components in order to maximize the reliability of a series system subject to multiple resource restrictions. After formulating and solving an associated zero-one programming problem by a branch-and-bound procedure, it is shown that the optimal solution to the associated problem is equivalent to the optimal solution for the optimal redundancy problem. Finally, it is shown that this method is relatively free of the problem of dimensionality that plagues the dynamic programming techniques, that it yields exact solutions, rather than the approximate solutions obtained by the linear, convex, or geometric programming methods, and that it can solve fairly large problems with multiple constraints in a reasonable amount of computer time and without excessive storage-place requirements. I.A.A.

Review: In this paper, a branch-and-bound algorithm is applied to determine the exact solution to the problem of maximizing the reliability of a multistage series system when it is subject to multiple resource constraints. Other techniques which have been applied to this problem include integerlinear programming, convex programming, dynamic programming, and geometric programming. The advantages of the method proposed in this paper include (a) the ability to handle problems of quite large dimensions, both in terms of stages and in terms of constraints, (b) the fact that it yields exact solutions, and (c) the fact that it can handle fairly large problems in a reasonable amount of computer time. The authors present a concise survey of previous literature in this area, citing eleven references, thus placing their work in perspective relative to the previous publications. The description of the procedure is also concise, and a prior knowledge of the branch-and-bound procedure will be a prerequisite to understanding it. A numerical example is given. This paper will be of interest to theorists concerned with the general redundancy allocation problem. Other papers on this topic are covered by R68-14065 (integer linear programming model incorporating multiple restraints), R68-14043 (also applying integer linear programming), R68-14044 (applying convex programming), and R69-14442 (applying geometric programming). The use of dynamic programming to solve mixed series and parallel problems was demonstrated in [1] (see review in this issue of RATR).

Reference: [1] R. M. Burton and G. T. Howard, "Optimum System Reliability for a Mixed Series and Parallel Structure," Journal of Mathematical Analysis and Applications, vol. 28, Nov. 1969 p. 370–382.

84 METHODS OF RELIABILITY ANALYSIS

R70-14975 ASQC 844; 612

National Aeronautics and Space Administration. Electronics Research Center, Cambridge, Mass.

INTRODUCTION TO COMPUTER AIDED RELIABILITY DATA ANALYSIS

Charles R. Toye Washington Feb. 1969 80 p refs
(125-25-04-91)
(N69-17988; NASA-TN-D-5009) Avail: CFSTI

This report describes the significant features required for the collection, coding, and documentation of hi-rel test data. It also contains a user's manual for the CARDA program, a third-generation computer program designed to fulfill the data reduction, analysis, and presentation requirements found in high reliability component specifications. Author

Review: This report is an introduction to the computer program: "Computer Aided Reliability Data Analysis" rather than an introduction to the subject of using computers in the analysis of reliability data. Much of the report concerns the user interaction with the program in terms of formats, etc. There is little discussion of the formulas used or assumptions made. For example, it is undoubtedly presumed in calculating confidence limits that the distribution of times is exponential. It is not clear whether the tests are assumed to be for a fixed time or a fixed number of failures, and it does make a difference in the calculation of the confidence limits. Those who are interested in finding out what this computer program will actually do to the data and what manipulations they would have to perform in order to use the program will find the report of value.

R70-14995 ASQC 844
Texas Instruments, Inc., Dallas.
RELIABILITY HANDBOOK FOR SILICON MONOLITHIC MICROCIRCUITS. VOLUME 3: FAILURE ANALYSIS OF MONOLITHIC MICROCIRCUITS
Wilton L. Workman Washington NASA Apr. 1969 196 p refs
(Contract NAS8-20639)
(N69-25328; NASA-CR-1348; TI-03-67-04) Avail: CFSTI

The purpose of the handbook is to provide aid in determining the most effective application and understanding of monolithic microcircuits, and the most effective quality and reliability assurance controls for the circuits. This volume describes the following topics: (1) effective failure analysis methods; (2) a step-by-step procedure for performing failure analysis; (3) how to identify failure mechanisms and their causes; and (4) how to assess the results of a failure analysis and to establish a relationship between the findings and the affected parameters or characteristics. For Volumes I and II of this publication see N69-23225 and N69-23226 respectively. Author

Review: This ambitious report spans the failure analysis spectrum from practical techniques such as the electrochemical sharpening of tungsten probes and the removal of lids from encapsulated devices without damaging the devices, to the measurement of terminal properties of integrated circuits and small-signal analysis of transistors. Its value as a reference is greatly enhanced by an index. The report is at its best in describing the details of little-publicized techniques such as cross-sectioning and staining silicon chips or the previously-mentioned removal of a lid from an integrated circuit package. Technique cannot be learned by reading alone, but this volume gives the novice a valuable head start in his own trial-and-error training. A sequence of procedures for carrying out failure analysis is also described in detail. Common sense clearly is still highly valued in this art, but the author outlines an orderly system that appears applicable to a wide class of silicon devices. Some misleading or ambiguous points do appear, not surprisingly, for the report consists of some 200 pages of text and figures. These points are generally of the minor variety. The discussion of electron microscopy and the thermal scanner is short and less authoritative. The conclusion that the thermal scanner does not show the existence of isolated hot spots conflicts with reports from researchers studying second breakdown (see, for example, R69-14574). The discussion of electron microscopy does not include the very valuable secondary-electron mode of the scanning electron microscope which is gaining rapidly in popularity among semiconductor researchers as well as reliability analysts.

R70-15000 ASQC 844
Air Force Systems Command, Wright-Patterson AFB, Ohio. Foreign Technology Div.
EVALUATING THE INFLUENCE OF PLASTIC DEFORMATION TO THE DAMAGE SUSCEPTIBILITY OF MATERIALS FROM THE NATURE OF FATIGUE-STRENGTH CHANGE
V. A. Zhukov et al 3 Feb. 1969 12 p refs Transl. into ENGLISH from Prochnost Metallov Pritsiklichesikh Nagruzkakh Materialy (Moscow) 1967 p 76–82
(N70-14377; AD-694797; FTD-HT-23-689-68) Avail: CFSTI

The effect of preliminary tensile deformation on the fatigue strength of ferrous and nonferrous materials is examined. Samples were fatigue tested in pure shear at a frequency of 3000 cycles/min. The endurance limit was arbitrarily selected as 5,000,000 cycles. After undergoing plastic deformation in tension, some samples had their surfaces machined off to a depth of 0.2-0.3 mm. Before fatigue testing, all surfaces were polished with a rubber wheel. Microhardness tests along the cross section and near the surface showed no change in hardness after machining. The ratio of endurance limit at any tensile strain to that at zero strain was used to determine the effect of plastic deformation. The fatigue strength of type 35 steel in the normalized and tempered (650C) condition is given as a function of the number of cycles to failure. Author (TAB)

Review: This paper is of concern largely to those doing research in fatigue rather than to designers since it is not clear how the results will be translated directly into design decisions. The influence of plastic deformation which occurred prior to the fatigue test was studied. It is not surprising that on notched specimens there was some improvement in fatigue life, undoubtedly due to compressive residual stresses in the notch. The report is short, fairly easy to read (there are a few language difficulties in the translation), and contains experimental results of value. Even though they undoubtedly support widespread opinion, it is important to have these opinions backed up occasionally by experimental results.

R70-15001 ASQC 844
Air Force Systems Command, Wright-Patterson AFB, Ohio. Foreign Technology Div.
A NEW METHOD OF INVESTIGATING THE PROCESSES OF CREEP AND STRESS RELAXATION IN METALS AND ALLOYS
A. A. Chizhik 19 May 1969 17 p refs Transl. into ENGLISH from the Russian
(N70-14428; AD-694963; FTD-MT-24-525-68) Avail: CFSTI

A new method of testing metals for creep and stress relaxation, which requires no complex equipment and makes such tests possible en masse, was developed. The basis of the method is a specimen possessing low rigidity whose working part is a cylindrical spring of square cross-section. This type of specimen eliminates expensive equipment and substantially increases accuracy in the measurement of creep deformation. The proposed method is the first to permit organization of mass tests of the creep resistivity of boiler pipes of any geometry, including those for steam superheaters, screening equipment, and heat-exchanging apparatus. Author (TAB)

Review: As operating temperatures for metallic parts become higher and higher and as special metals are developed to meet particular operating conditions, the behavior of metal parts in creep becomes more important to the reliability of the structure. This report describes a new shape of specimen; it is essentially a hollow cylinder with a spiral cut away to make a coil spring whose element has a rectangular cross-section. Since deformations do occur during creep, it was necessary to solve a rather complicated differential equation for converting the results to useful numbers. The specimens are reportedly easy to make and simple to use; therefore, those who are engaged in creep studies should investigate the methods proposed in this report.

R70-15003 ASQC 844
SURFACE-CHARGE INDUCED FAILURES OBSERVED ON MOS INTEGRATED CIRCUITS
D. D. Forsythe (Fairchild Semiconductor Corp., Research and Development Lab., Palo Alto, Calif.) *Microelectronics and Reliability,* vol. 8, no. 4 Nov. 1969 p 339–347 8 refs

Surface-charge induced failures have been observed on p-channel MOS devices with either $n+$ channel stops or thick field oxide, where these failures would not normally be expected to occur. This paper describes the tests that were performed to determine the characteristics of the failure, to locate the failure within the active channel region of the device, and finally to identify the cause of the failure. It is shown that the surface-charge induced failures are caused by small open areas in the gate aluminum. Author

Review: This is a good *physics-of-failure* paper. The author first gives a concise explanation of the classical surface-charge failure. It is not too long to be boring to the knowledgeable expert and yet is clear enough for others to understand. The anomalous behavior is then explained in terms of the observed electrical characteristics, and, finally, the cause of failure is isolated. The failures are due to non-aluminized spots in the aluminized gate area. Not only the results but the techniques are of interest to reliability engineers. The paper is recommended reading since it has the rare virtues of being clear, competent, and easy to read.

R70-15005 ASQC 844

EXPERIMENTAL VERIFICATION OF PROOF-TEST LOGIC

J. E. Collipriest, Jr. and D. E. Kizer (North American Rockwell Corp., Space Div., Downey, Calif.) *(Western Metal and Tool Conference, Los Angeles, 1969, Paper)* *Metals Engineering Quarterly*, vol. 9, no. 4 Nov. 1969 p 43–48

The results of preliminary crack-growth testing showed that the simplified proof-test logic was totally inadequate and inapplicable for the Saturn S-II cryogenic tankage materials. As a result, experimental procedures were developed to anticipate nondestructively the onset of final crack instability during the monotonic increase of proof loads. These involved crack-opening displacement (COD) measurement techniques, COD testing of precracked weld specimens, and life cycle testing of precracked weld specimens. It was concluded: (1) The simplified fracture-test procedures and proof-test logic assume that proof loading does not materially alter the size or growth characteristics of a pre-existing crack. On the contrary, the materials tested exhibited both crack-size and growth-characteristic changes. (2) Simplified proof-test logic predictions should be verified by complete life cycle specimen testing. (3) Simplifying and conservative assumptions should be carefully reviewed and assessed each time fracture data are analyzed or proof-test logic predictions are made. M.G.J.

Review: This paper deals with the reliability of the structural tankage of the Saturn V second stage (S-II). It is a good paper and shows the difficulties that can arise when one attempts to apply a theory to a practical situation. In this case, the theory is that involved with fracture mechanics and is concerned with whether cracks will propagate to failure or will not grow, at a given stress. The paper is recommended reading for anyone involved with practical applications of this theory. Those reliability engineers who are mechanically/metallurgically inclined should also be concerned with the points the authors are making.

85 DEMONSTRATION/MEASUREMENT

R70-14964 ASQC 851; 824

THE THERMALLY ACCELERATED TESTING OF ELECTRONIC COMPONENTS

A. C. Brown (S.T.C. Semiconductors Limited, Footscray, Sideup, Kent, England) *British Journal of Applied Physics*, vol. 2, ser. 2, Aug. 1969 p 1189–1192 1 ref

This paper indicates a possible extension to the Arrhenius theory of thermally accelerated life testing which might allow it to explain the manner in which failure rate varies with time during tests. Author

Review: This paper deals with the creation and analysis of a mathematical model; only a modest effort is made toward fitting experimental data. Briefly, what the author has done is to assert the rope model wherein all strands must fail before the system fails. Another model will give the same kind of answer, i.e., the weak link or chain model wherein the system fails when any one of its components fails.. If each link has the Weibull distribution (all have same shape parameter), then the chain has the Weibull distribution; the analysis of this model is quite conventional and well done in the literature. One could then assert that the scale parameter in the Weibull distribution would obey the Arrhenius law. Unfortunately, both in the author's rope model and in the Weibull distribution, the shape parameter must be known or otherwise determinable from the experimental evidence. There are some minor difficulties with this paper. (1) The Weibull curve itself does not have a flat portion, contrary to the author's indication. What the author has drawn is apparently the so-called bathtub curve. (2) It is by no means universally agreed that the logarithm of time to failure has a Gaussian distribution as would be required in part of the author's discussion (this is the lognormal distribution). The author has privately stated that "the paper was written to point out that deviations from the Gaussian distribution, observed experimentally, did not necessarily imply a failed experiment, but might be explained by a slightly different mathematical model." As a research note, this is an interesting little exercise, but not really new.

R70-14976 ASQC 851; 844

International Business Machines Corp., Owego, N.Y. Federal Systems Div.

RELIABILITY INVESTIGATION OF MULTILAYER INTERCONNECTION BOARDS (MIB'S) Final Technical Report, Sep. 1967–Oct. 1968

H. C. Hurley, L. F. Briggs, M. E. Pilling, T. M. Strong, and M. A. Young Feb. 1969 370 p refs

(Contract F30602-68-C-0019)

(N69-38532; AD-68945; IBM-68-354-021; RADC-TR-68-596)

Avail: CFSTI

The results of a test program to investigate failure mechanisms of multilayer interconnection boards (MIB's) are reported. The overall objective was a more fundamental understanding of the reliability characteristics of MIB's, as related to design, manufacturing and environmental variables. The test approach used was an experimental type of accelerated testing, called enhanced-defects' testing. Implementation was successfully carried out using two special MIB test vehicles designed to exhibit controlled-enhancement of failure occurrence during environmental tests. Test samples were prepared by marginal off-setting of selected design and processing variables. Test results for MIB open failure modes revealed a PTH-fracture failure mechanism which occurs as a result of temperature change, and is relatable to MIB material properties, PTH geometry and processing variables. MIB short failure modes were shown to be largely dependent on temperature and relative humidity but also relatable to MIB design variables, e.g., line spacing and processing variables. Failure models for MIB failure mechanisms are postulated. Author (TAB)

Review: This report obviously is of interest and value to those concerned with the production or use of multilayer interconnection boards (MIB's). The report is most detailed; there are a great many charts and graphs describing the results. Some of the mathematical models used to analyze various types of defects are shown. Most of these models are fairly crude, but nevertheless quite effective in estimating the magnitude of some effects. The conclusions appear reasonable in view of the experimental evidence. This report is of interest to a wider group because of the technique used for accelerated testing. In particular, the way "defect enhancement" was used should be studied for possible application elsewhere. Some of the MIB's were intentionally made weak in some particular strength areas in order that failures could be induced by reasonable "stresses" in a reasonable length of time. The results of this kind of test are not useful in calculating a failure rate, but they are very useful in finding the engineering properties of the MIB's, their potential failure modes, and ways in which the boards could be improved. The problem of having to test an inordinate number of boards for too long a time, that was faced by the engineers on this project, also confronts other reliability and design engineers in evaluating many of today's electronic and mechanical components. Those who are interested in only this phase of the report need read only the first few pages wherein the methods and conclusions are well given.

87 MAINTAINABILITY

R70-14986 ASQC 872; 821; 822
USED ITEM REPLACEMENT POLICY
B. R. Bhat (Univ. of Western Australia, Perth, Australia) *Journal of Applied Probability,* vol. 6, no. 2 Aug. 1969 p 309–318 3 refs

The block replacement policy, wherein items are replaced at regular intervals of time and on failure, is rather wasteful because sometimes almost new items are also removed. As an alternative a policy of replacement by new items at regular intervals of time and by used items on failure, is suggested. The consequences of this policy, called used item replacement policy, are studied for Erlangian and sub-exponential life-time distributions. The latter distribution which is the difference of two negative exponential distributions, does not seem to have received much attention in the literature so far. Author

Review: A block replacement policy involves the removal of some items which have not failed. The rationale put forth in this paper is that these used but nonfailed items be installed to replace failed items, subject to the provision that no item is used more than twice. The paper consists of an investigation of the mathematical properties of this policy for the Erlangian and sub-exponential lifetime distributions. The sub-exponential is defined as the difference of two negative exponential distributions, each multiplied by a suitable factor so that a density function results in the positive range of the independent variable. The mathematics was not checked in detail, but on the basis of a spotcheck it appears reasonable. This paper will be of interest to the theorist concerned with the modeling of maintainability, and makes a worthwhile contribution in this area. The rationale has cost-effectiveness implications, which are worth looking into in specific cases, especially those in which new items are quite expensive, but cost of replacement is relatively low. As the author has pointed out, the cost of the used item could include some minor expenses related to repair or reconditioning. However, this paper is not really concerned with practical implications of the policy, but rather with its mathematical properties. Nor does the paper go into replacement policies in general, although it does make brief reference to the age replacement, block replacement, and replacement-on-failure policies.

88 AVAILABILITY

R70-15007 ASQC 882
SYSTEM AVAILABILITY AND SOME DESIGN IMPLICATIONS
Irwin W. Kabak (New York University, New York, N.Y., and Modelmetrics, Inc., Edison, N.J.) *Operations Research,* vol. 17 Oct. 1969 p 827–837 11 refs
(A70-11382)

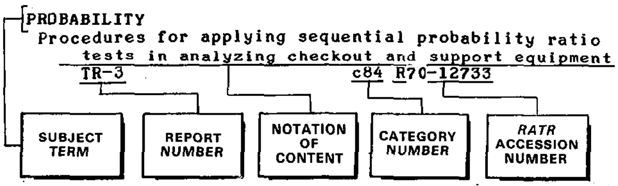
Detailed analysis of a system with an exponential reliability function and a constant repair time. The availability and its variance are presented for a given number of cycles, a finite length of time, and a steady state. It is then shown how the variance of the availability can be used to support an economic evaluation of start-up operations. Some design criteria are given based on a total system cost model that includes a function of the availability (a down-time that is the complement of availability). The work gives optimal values of the mean time to failure and the mean repair time, and exhibits methods for a sensitivity analysis of these optimal values and of the total system. Author (IAA)

Review: This is a mathematical paper concerned with availability for a given number of cycles and for a given length of time. The author makes reference to a number of the better-known textbooks on the mathematical theory of reliability, indicating that the problem which he is considering is one not usually considered in the literature. The specific reference in this paper is to an exponential reliability function and a constant repair time. However, the type of analysis can be applied to other reliability functions and other repair times. The mathematical model is described and the availability is obtained for one cycle and for multiple cycles, the steady-state, and finite time. An approximate evaluation of the variance of the finite time availability is given. This variance can be used to obtain probability bounds on the availability and is, therefore, useful in analyzing the economic aspects of the system. Two examples are given. The applicability of the results in determining optimal design parameters is discussed. This paper makes a worthwhile contribution to the theory of availability, and also indicates the practical utility of the results obtained.

SUBJECT INDEX

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS VOLUME 10 NUMBER 4

Typical Subject Index Listing



The Notation of Content, rather than the title, is used to provide a more exact description of the subject matter. The category number and *RATR* accession number are used to locate the abstract-review appearing in the abstract section of *RATR*.

A

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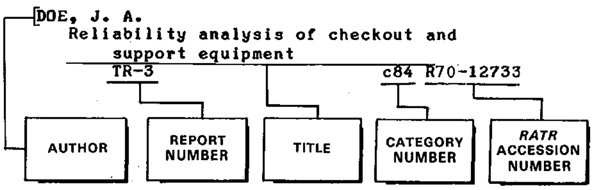
PERSONAL AUTHOR INDEX

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS VOLUME 10 NUMBER 4

Typical Personal Author Index Listing



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This may be used to identify the *RATR* accession number of reports covered in this journal. To the right of each report number is the *RATR* accession number preceded by the category number for locating the abstract-review in the abstract section of *RATR*. For purposes of this index, AD, N, and A numbers (accession numbers from *TAB, STAR*, and *IAA*, respectively) and ASQC code numbers are treated as "report" numbers. Thus, the section of this index listing ASQC codes may be used to identify the *RATR* accession number of the coded abstract-reviews appearing in *RATR*.

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This list of *RATR* accession numbers may be used to identify the category in which a numbered abstract-review appears in the abstract section of this journal. Accession numbers are arranged in ascending order. Preceding each accession number is the category number for locating the abstract-review in the abstract section of *RATR*.

MAY 1970

Volume 10
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R70-15012—R70-15059

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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General Equipment Company, Banville, Calif. ← **CORPORATE SOURCE**
TITLE → **RELIABILITY ANALYSIS OF CHECKOUT AND SUPPORT EQUIPMENT**
AUTHOR → John A. Doe 23 Sep. 1969 27 p refs ← **PUBLICATION DATE**
CONTRACT OR GRANT → (Contract NAS15-13411) ← ***TAB* AND *STAR* ACCESSION NUMBERS**
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Joseph A. Smith (Eastern University, Arlington, Penn.) ← **AUTHOR AND AFFILIATION**
JOURNAL REFERENCE → *Electric Journal*, vol. 8, Apr. 1969, p 478–492.
(A69-12569) ← ***IAA* ACCESSION NUMBER**

***RATR* ACCESSION NUMBER** → R70-12765 ASQC 773; 221; 823 ← **ASQC CODES**
TITLE → **TESTS OF SYSTEMS WITH SOME DEPENDENT FAILURES**
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B. James White (General Equipment Company, Banville, Calif.) ← **AUTHORS AND AFFILIATIONS**
CONFERENCE OR SYMPOSIUM REFERENCE → *Association of Reliability Engineering, Failure Rate Conference, Olney, Tex., Mar. 13–17, 1969, 8 p.* Available from Assoc. of Reliability Eng., New York: $1.00 ← **AVAILABILITY AND PRICE**
***IAA* ACCESSION NUMBER** → (A69-12407)

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A Monthly Publication

of the National Aeronautics and Space Administration

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80 RELIABILITY

No abstracts in this issue.

81 MANAGEMENT OF RELIABILITY FUNCTION

R70-15028 ASQC 810

THE SYSTEMS APPROACH TO PRODUCT FAILURE PREVENTION

J. M. Leinonen (Ford Motor Co., Dearborn, Mich.) *Mid-Year Meeting of the Society of Automotive Engineers, Chicago, May 19-23, 1969, Paper* 12 p refs

Product failures in the customer's hands can be minimized through the use of a disciplined approach to vehicle proveout. In this paper, the Ford truck systems engineering approach to product failure prevention is presented including definition of objectives, program reviews, testing, manufacturing and processing considerations, control of critical supplied components, and periodic status assessment. In addition, the techniques used to resolve critical component failure problems during a new vehicle experimental development program are discussed. Author

Review: One of the many useful spin-offs from the space program has been the reliability discipline. This paper shows how the reliability discipline has been applied in the automotive industry. The watchword, of course, is attention to detail and the author shows some of the ways in which this attention is assured. The paper is rather short and is of necessity general, but it does get the idea across and can make useful reading for managers and others who may be given the responsibility for a reliability program in industry. Recent graduates from school should realize that a paper such as this cannot present the daily trauma and wranglings that can arise in the application of any program where men are trying to meet their responsibilities and each one has a somewhat different point of view. It is in the way in which these disagreements are resolved that is the true test of management's intentions and desires (and reliability too often comes up short).

R70-15032 ASQC 813

PRODUCT RELIABILITY PROGRAMS INVOLVE MORE THAN MATHEMATICAL METHODOLOGY

H. S. Tolan, Jr. and J. Forgione (Ford Motor Co., Engineering Staff, Dearborn, Mich.) *Mid-Year Meeting of the Society of Automotive Engineers, Chicago, May 19–23, 1969, Paper* 19 p

A set of idealized engineering/manufacturing operational controls which can serve as models to mass production industry managements interested in implementing corporate-wide product reliability programs is disclosed. Emphasis is on the modus operandi with which management should be acquainted and should support if the most effective use is to be made of the existing body of reliability methodology. The elements of a reliability program are defined, and a sound product specification system is shown to provide one of the most crucial elements. New specification system concepts are presented which dictate the policies, procedures, organizational structures and personnel responsibilities necessary to design and produce reliable products. Author

Review: As the authors suggest, the maturing of the reliability discipline has been helped greatly by the space effort. This paper is an application of that reliability discipline to commercial products. Not every industry uses all phases of the discipline equally, and the authors are intent on showing that making a reliable product is much more than applying the appropriate mathematics. The aerospace industry is actually more in agreement with them than might be apparent since generally the more effective reliability programs are those which consider reliability an engineering and administrative matter, not a statistical one. Needless to say, the tools of mathematics/statistics are used but they must remain tools, not the ends. After a brief reply to critics of automotive reliability, the authors describe their approach to a product reliability program in terms of various specifications. This approach has much merit, and the main thing that is explicitly missing, although it may be implicit in some of the categories, is provision for review of the design and review of the manufacturing procedure. This review must be done by a relatively independent group, i.e., neither the design nor production engineer, and yet it must be done on a low enough executive level so as to be more than a defense of—or showing off of—established positions. This kind of review can be extremely helpful in getting changes made on paper where they are less expensive than they are in hardware. Recent graduates from school should remember that systems such as this do not implement themselves; they are implemented only by people not all of whom are perfect. This is true not only of the managers, engineers, etc., but also of the production workers, and a system which accounts for this imperfection is much more likely to produce

reliable hardware than one which does not. Few companies are as successful in their reliability efforts as their sales literature would indicate. It is not only customers of *automotive* companies who complain they must finish the manufacturing process, but customers of aircraft manufacturers as well. As the authors wisely point out early in their paper, it is the attitude and appreciative insight of top management that is an essential ingredient for the production of high-reliability products, and management makes its attitudes known not only in lofty pronouncements to the public press but also in the day-to-day decisions of running an operation. Employees are usually good at deciphering what management really wants (as opposed to what management says it wants) and quality and reliability are the things that most often suffer under these conditions.

R70-15041 ASQC 810
THE RELIABILITY PROBLEM
J. M. Groocock *Electronics and Power*, vol. 15 Nov. 1969 p 404–405

A distinction is drawn between reliability and quality control, and the difficulties and costs in time and money of reliability testing and measurement are examined. The methods developed for reliability engineering are outlined. The view is offered that the engineering designer often fails to get adequate feedback of information on reliability, and the customer has little chance of getting speedy information on the reliability of the products he receives. The importance of management interest in developing reliability engineering techniques is stressed. M.G.J.

Review: This is a general paper for newcomers (especially managers) to the discipline of reliability. It describes the difficulties in assuring reliability as opposed to the relative ease of insuring quality. Incentives for management and pressures on them are brought out well. The question of reliability mathematics is handled very nicely. A simple example is used to show order of magnitude difficulties, but there is no attempt to dwell on the elementary models used to calculate these numbers. The paper is short, easy to read, and uses a negligible amount of jargon. Therefore, it is recommended for those who wish to be introduced to the discipline of reliability and who have ready access to the paper.

R70-15049 ASQC 811
PROGRAM PLANNING AND ORGANIZATION
Leslie W. Ball (The Boeing Company, Seattle, Wash.) *In: Proceedings of the 1970 Annual Symposium on Reliability, Los Angeles, Feb. 3-5, 1970* Symposium sponsored by the Institute of Electrical and Electronics Engineers, Institute of Environmental Sciences, American Society for Nondestructive Testing, American Society for Quality Control New York IEEE, Inc. 1970 p 6-12 1 ref

The reliability organization, task identification, task assignment, and task accomplishment audit are described. Charts are presented which show the critical activities of the program manager, including decisions on selection of contractor, distribution of funds, organization, and other program level decisions. The quantitative requirements for reliability are given by the system specification and lower level specifications. The plan format of the availability and application of resources is mentioned, and the work breakdown structure/cost account plans are described which integrate the critical activities into the main stream of business management. The basic project organization is also illustrated showing the area staffed by assurance engineers. N.E.N.

Review: Reliability program planning at the overview level is presented in this rather brief paper. Those readers concerned with preparing such documentation may find useful thoughts in this paper, particularly in the ample illustrations. The material is timely and is oriented toward current Department of Defense directives. The program suggested in the paper is intended in part to solve the following problem noted by the author: Experience has shown that in the absence of massive engagement by the customer in the contractor's conduct of a development contract, reliability program plans [in the absence of other disciplines] do not give confidence that reliability will be achieved.

R70-15050 ASQC 815
SUBSYSTEM REQUIREMENTS
F. W. Mueller (Sandia Laboratories, Albuquerque, N. Mex.) *In: Proceedings of the 1970 Annual Symposium on Reliability, Los Angeles, Feb. 3-5, 1970* Symposium sponsored by the Institute of Electrical and Electronics Engineers, Institute of Environmental Sciences, American Society for Nondestructive Testing, American Society for Quality Control New York IEEE, Inc. 1970 p 13-19 8 refs

A rather basic approach to reliability modeling is presented, and some refinements that are useful in treating certain types of systems are discussed. Emphasis is placed on the interaction between reliability modeling and other mathematical models of performance characteristics. The relationship between reliability and quality requirements is identified. Consideration is also given to reliability modeling in terms of the broader aspects of systems analysis. Author

Review: This paper is a semi-tutorial review of the role that an overall system reliability effort can play in specifying subsystem requirements. Only the philosophical content would appeal to the specialist. It gives an historical introduction to reliability and further provides the reader with general technical background such as the difference and interaction between reliability and quality. The author's examples, though much simplified, give the reader an intuitive notion of the paper's content.

R70-15052 ASQC 815; 813
UPDATING OF RELIABILITY CRITERIA DOCUMENTS
H. R. Powell and H. J. Bailey (TRW Systems Group, Redondo Beach, Calif.) *In: Proceedings of the 1970 Annual Symposium on Reliability, Los Angeles, Feb. 3–5, 1970* Symposium sponsored by the Institute of Electrical and Electronics Engineers, Institute of Environmental Sciences, American Society for Nondestructive Testing, American Society for Quality Control New York IEEE, Inc. 1970 p 29–35

Topics requiring attention for updated criteria are discussed. The following are the major conclusions. The present reliability criteria documents promote an enforcer/informer type of contractor reliability organization, at the expense of the meaningful reliability support. The documents must be updated to include less input engineering and more output engineering. There should be fewer reliability reports, and more design reports containing reliability analysis. The basic reliability criteria documents must provide for the retention and use of reliability experience via the development of subsidiary technical documents. With respect to task problem pairs, the customer must be more explicit in defining the reliability requirement; reliability requirements must be stated in design engineering terms; and the form and phasing of traditional reliability analyses must be greatly changed to be effective on developmental projects.

Review: Some sensible recommendations for updating contractual reliability documents, such as specifications and standards,

and for planning reliability engineering activity at the lower implementation levels are given in this well-organized paper. The recommendations have a solid basis of experience. The reliability activity that is worth doing is sorted out from that believed not worth doing but which still may be noted in a reliability specification. This paper illustrates the fact that a contractor should not blindly implement the requirements of a specification. In a sense, the paper faults the government contractual documents a bit too much. These, of necessity, must be broad and comprehensive. There is usually opportunity for the contractor to clarify his interpretation and to exercise his technical judgment, particularly when this will rule out activity believed not worth doing. This paper also wrestles with innate problems of reliability engineering which have always accompanied formal reliability activity. One of these is the idea that the design engineer should really perform the tasks done by the reliability engineer. Thus, after about fifteen years, reliability engineering still has not found its comfortable niche, yet neither the government-customer nor, most likely, top contractor management would eliminate it.

R70-15053 ASQC 810; 850
ROLE OF PRODUCT EVALUATION FACILITY IN RELIABILITY
Paul N. Martin (SCM Corp., Stamford, Conn.) *In: Proceedings of the 1970 Annual Symposium on Reliability, Los Angeles, Feb. 3–5, 1970* Symposium sponsored by the Institute of Electrical and Electronics Engineers, Institute of Environmental Sciences, American Society for Nondestructive Testing, American Society for Quality Control New York IEEE, Inc. 1970 p 36–42 2 refs

Organizational and operational details are given on a facility whose primary function is the evaluation and testing of products from the viewpoint of the purchaser, the user, or the consumer. The contributions to reliability are cited as a second check on all factors associated with performance, endurance, user safety, convenience, survival of transportation environments, effectiveness of instructions, convenience for proper maintenance, and possibility for poor reliability resulting from faulty usage. Consideration is also given to how such an evaluation facility can be effective at various stages of new product development and introduction to the market; effectiveness in improving reliability of older products that continue in the product line, and of products manufactured by others and marketed under the corporate label; and evaluation and testing of competitive products with resulting feedback of ideas that can contribute to product reliability. It is pointed out that such a facility should be independent of any division or operation of the company and should be responsible directly to corporate management.
M.G.J.

Review: This paper is directed at providing management personnel with the requirements for, and the objectives and characteristics of, a separate product evaluation laboratory. The author's demonstration by means of his own company's laboratory is perhaps too detailed, but it still describes the attributes of such a facility in such a way that managements wishing to implement their own laboratories are aware of pertinent features. Toward this end, the paper concludes with recommendations regarding the position in company structure and the policy attitudes of such a facility. The paper did not give adequate attention to the idea (presented as an opening remark) of testing against potential consumer misuse of a product. It was not clear how the facility described would determine the "spectrum of misconduct" from other than the testing group's own experience. The paper did indicate (subjectively) how this form of testing would improve product image and thus increase overall marketing volume.

R70-15057 ASQC 810; 813
RELIABILITY FOR N/C MACHINES—A MUST
Rathin Neogy (Canadair Limited, Montreal, Canada) *In: Proceedings of the 1970 Annual Symposium on Reliability, Los Angeles, Feb. 3–5, 1970* Symposium sponsored by the Institute of Electrical and Electronics Engineers, Institute of Environmental Sciences, American Society for Nondestructive Testing, American Society for Quality Control New York IEEE, Inc. 1970 p 101–105

The need to introduce a formal reliability program that is specifically directed toward numerically controlled (N/C) machines is discussed. Among the techniques used to reduce N/C machine downtime, and maintain operational cost effectiveness and quality hardware are: (1) Downtime analyses are conducted for individual machines to identify areas requiring special investigation. A system coding is established and percentage downtimes allotted to each system and subgroup. (2) Design and reliability reviews are conducted on problem areas as identified by the downtime analyses. (3) Preventive maintenance procedures are reviewed and modified to suit particular type machines and production demands. Objective analyses and cooperation between the manufacturer and user are seen as prerequisites in an effective reliability program.
M.G.J.

Review: This author makes a good point. When reliability is looked at as an engineering discipline (rather than as a mathematical exercise), a great deal of improvement can be made in hardware. He also emphasizes that this improvement can be made not only in the hardware being manufactured in the plant but also in the plant equipment itself. In particular, the numerically-controlled machine tools used by virtually all aerospace manufacturers have an appreciable amount of downtime due to the lack of an organized reliability effort. The paper gives a case history in which a design defect was responsible for severe downtime. It yielded readily to an organized approach to its solution, but had been going on for several years prior to that organized approach. A large portion of this reliability effort consists of deciding upon the details which are important and then paying attention to them in an organized, methodical way. The paper helps to point out to us that all manufacturers are consumers as well as producers and that the reliability effort can profitably be applied to areas in which they are consumers as well as those in which they are producers.

82 MATHEMATICAL THEORY OF RELIABILITY

R70-15012 ASQC 824; 831
IMPROVING COMMUNICATION RELIABILITY BY USE OF AN INTERMITTENT FEEDBACK CHANNEL
Anthony J. Kramer (Sylvania Electronic Systems, Western Div., Mountain View, Calif.) *IEEE Transactions on Information Theory,* vol. IT–15, no.1 Jan. 1969 p 52-60 15 refs
(Contract Nonr-225(83)NR373-360)
(A69-21315)

The work describes and analyzes a feedback communication scheme where the feedback channel is used only to inform the transmitter, at specified times (prior to a final decision), which message the receiver considers most likely. The feedback informa-

tion is used by the transmitter to modify its transmission according to a rule known also to the receiver. When orthogonal signals are used and only an average transmitter power constraint is imposed, the error probability can be made to decrease in an N-fold exponential manner with increasing coding delay, where N-1 is the number of feedback interactions per message. This is in contrast to only a double exponential behavior for the error probability with some previously proposed feedback communication schemes. If a peak transmitter power constraint is also imposed, neither the N-fold exponential nor the double exponential behavior can be obtained. The peak power constraint limits the error probability expression to only a single exponential form. Author (IAA)

Review: Improvements in the reliability of a system can often be made by modifying either the hardware or the software. The approach taken in this paper is to improve the software. The paper is presented as a theoretical one, but some attention is paid to the feasibility of the various plans. The mathematics appears to be competent although it was only spot-checked. In this type of analysis, success/breakthroughs come by judiciously choosing which of the ordinary constraints can be thrown out and which ones are retained. It also pays, as the author has done, to make all of the assumptions very explicit. This enables the process of sorting out the constraints easier. Unfortunately it is also necessary to make tractable assumptions rather than entirely realistic ones, which makes the applicability of the results more uncertain. This paper is a good contribution to the reliability of communication systems, since it gives designers and analysts more options with which to work.

R70-15014 ASQC 824

Israel Inst. of Tech., Haifa. Faculty of Industrial and Management Engineering.

OPTIMIZATION OF INSPECTION POLICIES BY CLASSICAL METHODS

Z. Kander and P. Naor Apr. 1969 22 p refs *Its* Operations Res., Statistics and Econ. Mimeograph Ser. no. 36

(Contract F61052-68-C-0014)

(N69-37006; AD-688919) Avail: CFSTI

Inspection models deal with operating systems whose stochastic failure is detected by observations carried out intermittently. Previous authors calculated an optimal policy for a system possessing a given life time distribution. In these models two types of cost are introduced: one pertains to the expense incurred for each check; the other is associated with the time which elapses between system failure and its discovery at the subsequent check. The optimal policy is a sequence of checking times minimizing the loss per life cycle or, alternatively, per time unit. The technique of differentiation is used in order to arrive at the minimal loss solution. The present study deals with some additional models; in particular; (a) a truncated inspection model, in which costs for both unscheduled and scheduled replacements are introduced. The optimal policy is then given by a finite time sequence. (b) mixed models in which monitoring is considered in addition to checking. It is demonstrated by numerical results that the use of these policies will generally result in smaller losses than those associated with previous models. Author (TAB)

Review: This is a mathematical paper. There is no discussion of the relative applicability of the different models considered. It appears to be implicitly assumed that a failed system is replaced by a completely new system. (This is because only one density function for the lifetime distribution is given.) This is an important restriction. The mathematics was not checked in detail, but it seems to be competent. It will require some statistical and mathematical sophistication to follow the paper, largely because of its terseness rather than its complexity. The table of numerical results does help illustrate the theory. No general comparisons are made between the models except to show some ways of making the models equivalent by redefining variables. Thus, the paper is of interest to theorists rather than to design and reliability engineers.

R70-15015 ASQC 824; 552

New York Univ., N.Y. Dept. of Industrial Engineering and Operations Research.

INTERVAL ESTIMATES FOR P-N PLOTS OF FATIGUE DATA, WITH SPECIAL REFERENCE TO THE WEIBULL DISTRIBUTION

John H. K. Kao 15 Jul. 1969 35 p refs

(Contracts DA-31-124-ARO(D)-338; Nonr-285(62))

(N69-39882; AD-690877)

Probability papers for various fatigue life models such as normal, lognormal, exponential, gamma, Gumbel, Weibull distributions are graph papers with their coordinates modified so that, under the respective distributions, the probability failure, P in percent associated with the fatigue lifelength, N in number of cycles would form a straight line. Such graphical exhibits of fatigue data are known as P-N plots which are widely used by engineers to evaluate the fatigue characteristics of specimen, parts or structures. However, a P-N plot reveals only a series of point estimates for the true fatigue lifelength distribution function. In order to assess the goodness of these point estimates, confidence intervals are necessary. The report has concerned itself on three interval estimates. They are: (1) Nonparametric tolerance intervals, (2) Order statistic probability intervals, and (3) Parametric confidence intervals. These intervals are constructed around the P-N plots with a preassigned confidence coefficient. As the Weibull distribution is an important statistical model in fatigue testing, it is treated in some detail. TAB

Review: This is a good report. It is written in a language which most engineers will be able to understand if they are at all familiar with elementary probability and statistics. Even though it is not intended to advance the state of the statistical art, it is a good tutorial paper for reliability engineers and those interested in fatigue. The discussion is directed toward fatigue and the examples are largely of the Weibull distribution, but the techniques obviously have wider application in the field of reliability. One of the most important things the report does is stress the uncertainty involved in interpreting the outcome of tests. The author's Table I is especially valuable in this regard since it is distribution free and shows vividly how great the uncertainties really are compared to the engineer's intuitive feeling of accuracy. (Unfortunately, the table itself is poorly labeled even though it is given in the exact format of Table 36 of the author's Reference 3, which is a classic and presumably quite familiar to workers in this area. The horizontal dimension is the total number of specimens; the vertical dimension is the order number of a failed specimen, and the body of the table gives the upper and lower interval limits in percent.) It would have been interesting had the author discussed the relationship of this table (where all specimens are failed) to the Kolmogorov-Smirnov statistic/test with which many reliability engineers are familiar. Readers should note that pp. 11-16 and Figs. 5-10 contain material which is new. A graphical device avoids complicated computations.

R70-15018 ASQC 821; 615

LIMITED COST PROVISION OF A FUNCTIONALLY RELIABLE MULTICHANNEL SYSTEM SERVICED ACCORDING TO A CONTINUOUS GRAPH

M. M. Lastovchenko and L. A. Sidorov *Telecommunications*, vol. 23, no. 4 Sep. 1969 p 26-32 7 refs

Multichannel system functioning when preventive maintenance and repair work are carried out on individual channels directly during the operating time is considered. A method is described for estimating the readiness of the system in terms of the numbers of service staff and stand-by channels. Maximization of the readiness by optimizing staff and stand-by organization is discussed. Author

Review: This paper generalizes the results of some previous papers in this area and is of interest primarily to theoreticians. The objectives of the paper apparently are: (1) to derive a figure of readiness (probability that a system will operate properly at any given instant) for a system with repairable stand-by, as a function of its complexity, reliability and servicing characteristics, and (2) to investigate the sensitivity of the system readiness to its parameters. The author gives the assumptions upon which the results are based. The mathematics was not completely checked, but it appears to be competent. The major deficiency for U.S. readers is that the authors rely heavily upon the results of previous Soviet papers which are not readily available.

R70-15025 ASQC 824; 612

California Univ., Berkeley. Operations Research Center.

THE AUTOMATIC CALCULATION OF THE RELIABILITY OF COHERENT STRUCTURES

Robert Larribeau, Jr. Mar. 1969 49 p refs

(Contract Nonr-3656(18); Grant NSF GK-1684)

(N69-31752; AD-686156; ORC-69-4) Avail: CFSTI

A computer program is described that permits the calculation of the exact reliability of complex systems. The concept of a Coherent Structure is used to represent the system as a two terminal network. This thesis describes the data structures and algorithms needed to take the two terminal network, produce the proper arithmetic expression, and do an evaluation to find an exact reliability. Author (TAB)

Review: This is a mathematical paper and as such will have limited appeal to design and reliability engineers unless they are quite theoretically inclined. The algorithms were not checked in detail, but their description appears reasonable. The complexity in enumerating the success paths is kept low by generating equivalent single elements from parallel or series elements, until there are no series or parallel elements left. The number of equivalent elements in the network is then hopefully small enough so that the enumeration task will not swamp the computer. On page 21, the author states ". . . until a pass is made over the network it does not cause any changes. When this happens, we are left with either a bridge network or a network consisting of the two terminal nodes and one arc connecting them." Since the author has used the bridge network in his examples only referring to the usual five-element network shown as a bridge, it is not clear that here he must be using the term bridge in its generalized sense; i.e., any structure no matter how complicated that has no series or parallel elements in it (the network represented by the edges of a cube with input and output nodes on a diagonal is an example of a complicated bridge network). It might be worthwhile to generate a more popular treatment of this method; it could give the FORTRAN program and the required I/O formats with an example of how to use it, omit all the theoretical explanation, and refer to this paper for the theory. In this way, the method would become more accessible to reliability engineers and they could decide when it would be possible for them to use it. It might be an interesting exercise to introduce a new operator which changes a delta network to a wye network (as is common in electrical power engineering) and vice versa. By this means, a much more general class of network could be reduced to the simple case of one arc and two nodes. The editorial polish of the paper is not high, but the errors are generally recognizable by anyone familiar with the subject.

R70-15026 ASQC 824; 431

LOAD HISTORY EFFECTS IN STRUCTURAL FATIGUE

H. Akaike (Institute of Statistical Mathematics, Tokyo, Japan) and S. R. Swanson (MTS Systems Corp. Minneapolis, Minn.) *1969 Annual Meeting Institute of Environmental Sciences, Anaheim, April 23, 1969, Paper* 13 p

(A69-30363)

Review of the basic mechanism of metal fatigue, referring to the type of loading reviewed by Swanson (1968). For many vehicles, it is often found that a careful collection of loading data results in a linear relationship between the load level and the logarithm of exceeding a given load level. The progress and present technology of applying such a load spectrum in the laboratory is discussed. IAA

Review: This is an interesting paper even though the connection between the content and the title is tenuous. The paper deals largely with the fact that many fatigue loadings under service conditions contain a great deal of uncertainty, and the best way to simulate them in the laboratory is with random processes. In particular, the authors suggest several relationships for the parameters of the random process. It is not always clear in the discussion of the theory what the very basic assumptions are, and which are made for mathematical ease of handling. For example, in the statement on page 3, ". . . we must now make the assumption that we are dealing with intrinsically Gaussian phenomena," the *must* is not clear. The paper is largely mathematical, and in order to follow it one needs to have some familiarity with probability and statistics. The description of fatigue loads as a random process is worthwhile, and if one does not possess the background to follow the discussion in those terms he will have to acquire it to understand future developments in fatigue. Another point to keep in mind is that safety factors and safety margins are being cut so close these days (due to the improved adequacy of testing) that it is difficult to be sure that the properties of a large batch of metal will be the same as those from which previous specimens were tested. In work with very high reliability, this can be a most important consideration.

R70-15030 ASQC 823; 413

A NOTE ON THE TEST FOR THE LOCATION PARAMETER OF AN EXPONENTIAL DISTRIBUTION

Kei Takeuchi (New York Univ., New York, N.Y. and Univ. of Tokyo, Tokyo, Japan) *Annals of Mathematical Statistics*, vol. 40, no. 5 1969 p 1838–1839 3 refs

Theorems are proved for the UMP (uniformly most powerful) test for the location parameter of an exponential distribution. Author

Review: This is a theoretical paper. It deals with the exponential distribution in the presence of a guarantee period. It will be of value (in the reliability field) only to statisticians who are interested in making statistical tests concerning an estimate of the guarantee period.

R70-15034 ASQC 821

THE RELIABILITY FUNCTION OF A FINITE AUTOMATON

A. N. Sklyarevich *Engineering Cybernetics*, no. 1 1969 p 91–

96 3 refs

The reliability function of a finite automaton and the mean number of cycles to its failure are found. Taken into consideration are the probabilistic appearance of possible errors, the structure of the automaton, and the distribution law of the input signals. Author

Review: Persons concerned with the reliability of complex digital circuitry will be interested in this paper. It derives an approximate expression for reliability which takes into account changes which occur in the transition matrix of a finite-state machine as its elements fail. It allows for the possibility of the failure of more than one element before failure is observed in the output. The translation (from Russian) is quite good. The mathematics of the derivation is tedious but can be followed reasonably well by persons with an average background in applied mathematics. The derivation was not checked in detail but appears competent.

R70-15037 ASCQ 824; 612

Naval Postgraduate School, Monterey, Calif.

EVALUATION OF THE ACCURACY OF A RELIABILITY MEASUREMENT PROCEDURE USING SIMULATION TECHNIQUES

Kenneth Alan Huffman (M.S. Thesis) Dec. 1968 46 p refs
(N69-7717; AD-688460) Avail: CFSTI

The study evaluates the accuracy of an established reliability measurement procedure by computer simulation. The reliability measurement procedure assumes components fail according to an exponential failure law. This study tests the accuracy of that procedure when components obey a Weibull failure law or a log normal failure law. Author (TAB)

Review: The users of the *Guide Manual for Reliability Measurement Program* (NAVWEPS OD 29304) will find this to be an interesting and useful paper. Through computer simulation, the effect of falsely assuming that components have a constant failure rate in the calculation of system reliability is evaluated for situations where failures follow a Weibull or Log Normal failure law. Although this paper is by no means a complete evaluation of the procedures outlined in the *Guide Manual,* the author is to be commended for his initial efforts. Only eight cases, each involving four components, were evaluated. As a measure of accuracy of the *Guide Manual* procedure the author uses the statistic $|A_{1-\alpha} - R_S|$, where $A_{1-\alpha}$ is the $(1-\alpha)$ per cent point on the distribution of $\hat{R}_{S,L(\alpha)}$ and R_S is the true system reliability. $\hat{R}_{S,L(\alpha)}$ is the lower limit on R_S using the *Guide Manual.* He also mentions the mean and standard deviation of $\hat{R}_{S,L(\alpha)}$ as measures of accuracy. This point needs additional comments. The author also calculates another statistic, $\hat{R}_S = e^{-\hat{\lambda}}$, but does not adequately indicate how this information is utilized. It would appear that $|\bar{\hat{R}}_S - R_S|$ could also be used as a measure of accuracy, where $\bar{\hat{R}}_S$ is the mean of $\hat{R}_S$. For completeness, the paper should include some comments regarding the relationship of sample size, N_i, to accuracy, distribution of $\hat{R}_{S,L(\alpha)}$ and distribution of $\hat{R}_S$. It is interesting to note that as N_i increases from 50 to 500 (1) the expected value (mean) of $\hat{R}_{S,L(\alpha)}$ increases, (2) the standard deviation of $\hat{R}_{S,L(\alpha)}$ decreases, (3) the $(1-\alpha)$ per cent point of $\hat{R}_{S,L(\alpha)}$ is essentially unchanged, (4) the expected value of $\hat{R}_S$ remains stable, and (5) the standard deviation of $\hat{R}_S$ decreases. Equation (4) on page 15 is wrong. The terms should be multiplied rather than added. The results given in this paper should inspire more extensive examination and evaluation of the procedures utilized in the *Guide Manual,* especially by those using this procedure in calculating reliability of complex systems.

R70-15040 ASQC 824

Air Force Systems Command, Wright-Patterson AFB, Ohio. Foreign Technology Div.

USE OF STRUCTURAL RESERVES FOR INCREASING THE RELIABILITY OF AUTOMATIC DEVICES

E. N. Turuta 5 Feb. 1969 16 p refs Transl. into ENGLISH from Acad. Sci. USSR, Siberian Dept., Inst. Math., Computer Systems, Collection of Works (Moscow), no. 25, 1966 p 19–30
(N69-37301; AD-688095; FTH-HT-23-863-68) Avail: CFSTI

The paper discusses a finite automan with the state set presented in the form of a system consisting of a combinational logic circuit and memory elements. Random malfunctions of the following type may occur in the logic elements and memory elements: an element that must issue 1 at the output issues O instead, and vice versa. The satisfaction of the following conditions is presumed: the probability of the distortion of the input signal of any memory element is low; the errors of various memory elements are independent and their probabilities p are the same for every element and do not vary in time and, further, p is greater than 1/2. To enhance the probability of correct transition, h additional memory elements are introduced into the automation and k of its states are encoded in the words of some code having the length n equals k plus h with k information symbols and h redundant symbols. All the binary sequences x of the length n that do not coincide with any of the code words are termed distorted states of the automation. TAB

Review: The title of this paper is somewhat misleading since the paper is actually concerned with error-correcting state assignments for sequential machines. The paper is an edited translation and is plagued with minor problems such as misspelled words, commas in place of decimal points, the number 9 (nine) looking like the letter g, and other symbols that are difficult to discern. However, the interested reader can overcome this handicap. The paper is technically sound and accomplishes the following two purposes: (1) a brief discussion of some theoretical aspects of the use of error correcting codes to achieve an error-correcting state assignment in a sequential machine, and (2) an example illustrating the application of a single error-correcting code in making a state assignment which results in the proper state transitions even when a single memory element is faulty. No consideration is given to the added complexity that would be required to implement the error-correcting state assignment. Although the material presented in this paper consists of well-known concepts and techniques, the author's example of applying an error-correcting state assignment might serve to clarify the approach to those engineers who are not already knowledgeable.

83 DESIGN

R70-15016 ASQC 833; 844

SELECTING MATERIALS TO RESIST LOW CYCLE FATIGUE

C. E. Feltner and R. W. Landgraf (Ford Motor Co., Scientific Lab., Dearborn, Mich.) *American Society of Mechanical Engineers, Design Engineering Conference and Show, New York, May 5-8 1969, Paper* 12 p refs
(A69-28852)

Procedure for ranking materials for selection in the design of components to resist low cycle fatigue. The criteria are resis-

tance to strength loss, repeated straining, repeated stressing, and notch fatigue in the low cycle fatigue region. Easily performed tests, requiring only two specimens of each material are described, involving the determination of monotonic and cyclic stress-strain curves from a standard tensile test and an incremental step test, respectively. A comparison of the two curves yields the tested material's cyclic stability immediately, and values from these curves can then be used in conjunction with empirical relations to predict fatigue resistance in terms of plastic strain amplitude, stress amplitude, and a fatigue notch parameter. Examples, using practical engineering materials, illustrate the reliability of the procedure. IAA

Review: This is a good, practical paper for designers. It accepts as facts of life that not everyone will be able to run extensive fatigue tests and that materials will often be selected on some other basis. The criteria suggested in this paper seem to be good ones, and designers ought to give them careful consideration. The paper does require some metallurgical sophistication to read, but most designers who are aware of these problems will possess the required knowledge to understand the authors' criteria.

R70-15017 ASQC 838
FAILURE-TOLERANT SEQUENTIAL MACHINES USING PAST INFORMATION
Yoshihiro Tohma and Susumu Aoyagi (Tokyo Institute of Technology, Dept. of Electronics, Tokyo, Japan) *Electronics and Communications in Japan,* vol. 51-C, no. 11 1968 p 95-101 15 refs

Conditions on state assignments, numbers of required redundant state variables, and estimates of reliability of failure-tolerant counters and sequential machines are described. It is proved that, if information of one clock period past is used for redundancy, a state assignment of the minimum distance two is necessary and sufficient for single-error correction, and one redundant state variable is sufficient for the implementation. Author

Review: This paper is an extension of previous investigations into error-correcting state assignments for sequential machines and can be of interest to both theoreticians and those engineers engaged in the design of reliable digital systems. Specifically, it is directed toward reducing the number of state variables necessary to realize an error-correcting state assignment. The approach that the authors take toward achieving the reduced number of state variables is to employ past inputs and past states as redundant information. Such an approach is of questionable practical value since the system complexity may be greatly increased by storing the required past information. Although the authors' notation is somewhat difficult to follow, several results are proven regarding the required number of redundant state variables for given minimum distance between state assignments and given usage of past information. The major weakness is that no information is given on the increased system complexity that is required to implement the proposed error-tolerant scheme. The authors have stated in a private communication that the past input and the information of the past state are easily obtained by delayed input variables and delayed state variables. Using a suitable clock system (for example, a two-phase clock system) delaying action can easily be realized by only one stage flip-flops. Hence, system complexity is not increased greatly, but the complexity of the logic network that determines the next state is inevitably increased.

R70-15019 ASQC 833
PLASTIC ENCAPSULATED SEMICONDUCTOR RELIABILITY - TODAY
Edward B. Hakim (U.S. Army Electronics Command, Electronic Components Lab., Fort Monmouth, N.J.) *1969 International Electronics Circuit Packaging Symposium (Wescon), Aug. 20-21, 1969, Paper* 7 p refs

An overview of published plastic encapsulated semiconductor reliability data shows that there is little agreement between the semiconductor manufacturers, the users, and the military on the qualifications of such devices. Variability in products between manufacturers, as well as inconsistent products from the same manufacturer, was found. However, application of these devices were also found in equipments which are noncritical, have life expectancies in days, and are nonretrievable. Although the services are pessimistic about the application of plastic semiconductors in high reliability systems, programs are being conducted to determine if general acceptance of these devices is possible. If they are, users will have a choice of either plastics or hermetics. It was concluded that plastic encapsulated semiconductors, in general, are not of sufficient quality to be considered equivalent to hermetics. For this reason, the military will continue to put restrictions on the use of these devices. Author

Review: This is a good paper. It presents just about everyone's conclusions on plastic encapsulated semiconductors, and it references each of those conclusions so that one can go back and check on the contexts in which they appear. This is an important topic in which manufacturers as well as users have a high stake. The paper brings out well the different opinions, especially the virtual dichotomy between users' and producers' opinions. Industrial users will find this article of interest and help, even though the primary beneficiaries are those involved with DOD/NASA contracts.

R70-15023 ASQC 830; 844
FORUM: FASTENERS MEET SUPERNEEDS OF AEROSPACE INDUSTRY
Metal Progress, vol. 96, no. 3 Sep. 1969 p 69-81 (A69-40822; A69-40823; A69-40824; A69-40825; A69-40826; A69-40827; A69-40828; A69-40829; A69-40830; A69-40831; A69-40832)

The important aspects of design, installation, materials, and testing are emphasized. The systems approach is stressed as a means by which fabricators can produce more efficient airframes and at lower costs. The mechanical properties of high temperature fastener alloys are examined, and the recommended service temperatures for titanium alloy fasteners are listed. Preventive measures used for protecting airframes against galvanic corrosion around fasteners are discussed. The question is raised as to whether joint fatigue tests are realistic, and it is concluded that the fatigue acceptance criteria and the actual anticipated exposure of fasteners to gusts are not comparable. The material requirements and testing of large-diameter bolts are examined, and crimping techniques for preventing loosening of nuts are described. Consideration is also given to the use of load-determining bolts, and to the role played by interference-fit fasteners in improving the fatigue life of an aircraft structure. Details are provided on a fastener which can be installed from one side of the joint, and on a titanium stress pin system which has a headed straight-shank pin and collar and which reduces the danger of fatigue cracks. M.G.J.

Review: Attention to detail is the watchword for reliability. This collection of brief papers deals with those details which are necessary to ensure a satisfactory fastening system for aerospace structures. Each paper stresses a somewhat different aspect of the system. As would be expected, virtually every aspect drastically affects the reliability of the structure. The reports are all good.

Several discuss individual fastener systems and, naturally enough in those cases, the advantages rather than the disadvantages tend to be pointed out. One method not included is under development at Ohio State University (and elsewhere), and uses high-frequency high-power vibrations to set a rivet. This report is of value not only to aerospace engineers but to others who may be faced with similar problems (and not realize it) and also to those mechanical and electronics designers who are not familiar with the intimate interaction between mechanical, metallurgical, and chemical considerations in a structure, and the practical considerations of ensuring that the proper conditions are met every time.

R70-15038 ASQC 831; 844

Iowa Univ., Iowa City. Dept. of Mathematics.

THE APPLICATION OF FAULT INDISTINGUISHABILITY IN COMBINATIONAL NETWORKS

James W. Gault Jul. 1969 97 p refs

(Contract N00014-68-A-0500)

(N70-11349; AD-692420; THEMIS-U1-TR-13) Avail: CFSTI

The desire is to reduce the dimensionality of test generation problems by removing sets of faults which are inherently indistinguishable prior to processing the network. Using these results computations are made to determine a fault detection test set using string manipulation and thus avoid the more difficult operations of symbol manipulation and simulation. Using the concept of indistinguishability, results are given for handling multiple as well as single faults. TAB

Review: This is a well-organized report which serves to widen the state-of-the-art in both fault detection and diagnosis of digital systems. The report contains both theoretical and practical information and will therefore be of interest to theoreticians as well as to engineers who are concerned with fault detection and diagnosis, redundancy verification, etc. The author renders the report essentially self-contained by providing an up-to-date review of previous efforts in fault detection techniques and by providing formal definitions of all key terms. The report employs the notion of Boolean difference as a means of generating input test sequences to check the logical integrity of combinational logic circuits. The treatment of Boolean difference is adequate for the author's purpose; however, the reader may find it helpful to consult his reference for a more detailed discussion. Several of his theorems which ought to prove useful concern the recognition and handling of redundancy and the detection of multiple faults. The reader interested in this topic should also find the following paper of interest: "A means of deriving minimal complete sets of test-input sequences using boolean differences," *IEEE Computer Group News* (Repository No. R-70-22), vol. 3, no. 1, Jan/Feb 1970.

R70-15043 ASQC 833

METALS REFERENCE ISSUE 1970

Machine Design, vol. 42, no. 4 Feb. 1970 p 1–238

A basic reference manual is presented on the engineering design properties of cast ferrous metals, wrought ferrous metals, nonferrous metals, and fabrication processes. Tables, charts, graphs, and illustrations are included to aid in the selection and application of the best metal, combination of metals, or metal working process. Producers and fabricators of metals and metal parts are listed under six major headings: (1) producers of wrought ferrous mill forms and shapes; (2) producers of wrought nonferrous mill forms and shapes; (3) producers of ferrous castings; (4) producers of nonferrous castings; (5) fabricators of formed and shaped parts; and (6) producers/fabricators index. M.G.J.

Review: This is a good and important publication for designers: it is a concise compilation of information about metals. Many designers will use this reference issue as their primary initial survey of metals for any new job. Unfortunately, an issue such as this cannot be concise and comprehensive at the same time. In the aerospace field, the properties concerned with failure need constant emphasis and, from that point of view, it would be helpful if a reference issue contained more failure information; for example, stress corrosion receives scant if any attention. Perhaps in some future issue, in addition to a section on fabrication processes, there could be one on failure modes and mechanisms. This would help educate designers and make them more aware of the ways in which metals fail. The section could also stress the importance of the variation in strength and life properties that exist within any given metal specification.

R70-15044 ASQC 835; 844

PACKAGING REQUIREMENTS FOR OPTIMIZED MALFUNCTION ISOLATION BY SYSTEMATIC SUBSTITUTION

Lyle R. Greenman (Martin-Marietta Corp., Orlando, Fla.) *IEEE Transactions on Aerospace and Electronic Systems*, vol. AES-5, no. 3 May 1969 p 499–514

(A69-29494)

Malfunction isolation technique primarily applicable to electronic systems. The technique is effective for essentially 100% of all failures, including multiple, intermittent, interconnection, and closed-loop failures, to the discard-at-failure (DAF) hardware level. The value of the technique, in addition to its simplicity and case of use, is that, in very complex systems, it virtually eliminates the requirement for complex procedures, high personnel skill levels, and manual test equipment necessary for malfunction isolation. The main essential of the technique is the packaging of the equipment. Each level of hardware must contain approximately four plug-in packages per package. Malfunction isolation is accomplished by substitution of packages in the top level, one at a time, until the defect is corrected. Next, the second-level packages in the defective top unit are replaced, one at a time, until the bad package at this level has been identified. The packages are substituted in each subsequent level until the DAF item is reached. When an equipment is packaged according to this technique, the average number of substitutions required to isolate to a single malfunctioned DAF item is approximately 1.8 times the natural logarithm of the number of DAF items in the system. For example, a system containing 4100 DAF items requires about 15 substitutions to locate a single defective item. The foregoing is true when no information is available regarding the best sequence of exchange. If such information is available, the number of substitutions will be reduced.

Author (IAA)

Review: This is a good paper on an interesting and timely subject. As systems increase in complexity, the corresponding need increases for providing simple, rapid means of isolating failures and making repairs. This particular malfunction isolation technique is readily amenable only to electronic systems employing modular packaging concepts. However, most package designers and maintainability workers will benefit by reading the paper, as some of the concepts can be applied to other systems. It is particularly noteworthy that the number of substitutions required to isolate a malfunction increases in proportion to the logarithm of the number of discard-at-failure items; hence, the advantages of this technique increase as system complexity increases.

R70-15048 ASQC 831

MISSION ANALYSIS IN SYSTEM EVOLUTION

Everett L. Welker (General Electric/Tempo, Support Systems

Analysis, Santa Barbara, Calif.) *In: Proceedings of the 1970 Annual Symposium on Reliability, Los Angeles, Feb. 3-5, 1970* Symposium sponsored by the Institute of Electrical and Electronics Engineers, Institute of Environmental Sciences, American Society for Nondestructive Testing, American Society for Quality Control New York IEEE, Inc. 1970 p 1-5 5 refs

Mission analysis is discussed in the context of the manner in which it is performed, and the way it is used in the system evolutionary process. The term system is defined as consisting of three basic elements: the overall mission, the condition under which equipment is to be operated and maintained, and the equipment or hardware involved. Since the mission analysis plays a significant role in the system development process, this role is described in terms of how mission analysis fits into the system and how the analysis is performed. Emphasis is placed on principles rather than on specific steps in the process of performing and applying mission analyses in system evolution. Portions of an Apollo type program are used to illustrate the concepts presented. M.G.J.

Review: This paper is clear, well written, and extremely uniform in its level of address. The author states his objective and then takes it to task. His use of the Apollo mission as an example is timely and very successful in relating his analytic structure to reader background. Further comment on generation of system output parameters from the system concept would have been a desirable addition. Also, the paragraph at the end of the paper regarding the GE time-sharing computer is well taken but could have been slightly de-emphasized as it did not significantly contribute to the author's objective.

R70-15051 ASQC 832

THE HUMAN ELEMENT IN SYSTEM DEVELOPMENT

Alan D. Swain (Sandia Laboratories, Systems Reliability Div., Albuquerque, N. Mex.) *In: Proceedings of the 1970 Annual Symposium on Reliability, Los Angeles, Feb. 3-5, 1970* Symposium sponsored by the Institute of Electrical and Electronics Engineers, Institute of Environmental Sciences, American Society for Nondestructive Testing, American Society for Quality Control New York IEEE, Inc. 1970 p 20-28 18 refs

A program and procedures are described which indicate the type of approach necessary to consider the human element in system development, with emphasis on quantifying the effects of human performance on attainment of systems criteria. It is stressed that the human element should be considered in every stage of system development from inception to use. It is felt that appropriate consideration of the human element will result in optimum tradeoffs among system reliability, cost, and other criteria, and reduce system failures due to the human element. N.E.N.

Review: More and more attention is being paid to the formal consideration of people as operators of the equipment and as part of the production process. This paper is directed toward designers and system planners and will provide them with valuable information. It is a good paper and should be given due consideration. One area not explicitly brought out is that designers and system planners are people and their tasks should be allocated to men or machines, depending on which can do the job more effectively.

R70-15054 ASQC 833

PARTS STANDARDIZATION AND PROFIT

R. N. McDaniel (Westinghouse Electric Corp., Baltimore, Md.) *In Proceedings of the 1970 Annual Symposium on Reliability, Los Angeles, Feb. 3–5, 1970* Symposium sponsored by the Institute of Electrical and Electronics Engineers, Institute of Environmental Sciences, American Society for Nondestructive Testing, American Society for Quality Control New York IEEE, Inc. 1970 p 55–63 16 refs

The benefits of standardizing complex electronic parts are discussed within the restraints of technology, organizations, military specifications, schedules, program requirements, and available dollars. Available alternatives are considered and, based on limited implementation experience, the most effective solution available to this very complex problem is recommended. Author

Review: Parts standardization is one of the concepts to which much lip service is given but to which in practice there is often considerable opposition. This author explains how parts standardization can increase profit and benefit the customer (government) at the same time. It is indeed a worthwhile goal, and the author not only gives sound reasons for trying to achieve it but also gives historical background and a recommended approach on ways of achieving it. It is a good paper on an important topic. Some of the recommendations may be controversial, but it is more important to select some set of recommendations and implement them than to argue forever about what is the best way. Designers, especially, have shown a traditional tendency to avoid standardization. This is usually because the emphasis in their design has been on the attribute of performance rather than on many other factors such as reliability, logistics, and purchasing. It is necessary to keep up the pressure in behalf of standardization in order that these attitudes may eventually change. It is perhaps also important to see that this concept finds it way into the schools and is at least mentioned in various courses in design and analysis.

R70-15055 ASQC 831; 612

SYSTEM EFFECTIVENESS ANALYSIS OF COMPLEX SYSTEMS

Julian Reitman (United Aircraft Corp., Norden Div., Norwalk, Conn.) *In Proceedings of the 1970 Annual Symposium on Reliability, Los Angeles, Feb. 3–5, 1970* Symposium sponsored by the Institute of Electrical and Electronics Engineers, Institute of Environmental Sciences, American Society for Nondestructive Testing, American Society for Quality Control New York IEEE, Inc. 1970 p 64–67

The use of computer simulation languages to reduce the difficulties of analyzing the tactical performance of complex systems is discussed. It is pointed out: (1) These languages permit models representative of the real world to be generated in a reasonable time and at low cost. (2) They are the key element needed to provide a common basis for problem definition, a structure for concept formulation, and a definition of the system for customer, designer, and computer. (3) Existing systems may be simulated with actual maintenance data to develop a validated computer model. Then, different operational regimes can be simulated and their performance anticipated before being implemented in the field. (4) To make the simulated performance coincide with that of the actual system, the simulation must include costs, support system characteristics, manpower skill level, technical performance capability, and failure modes. As a result, the simulation requires that the problem be arbitrarily limited to avoid having the system interact with an infinite number of other systems. Author

Review: A bit of the flavor of computer simulation for system effectiveness analysis is given in this paper. It consists entirely of discussion and is too short to be substantive. The contents become more specific when a particular computer installation is described briefly. The requirements for an effectively functioning computer installation such as described are formidable, including a large modern computer, a simulation language, input/output devices,

data libraries, and personnel who can interact effectively with this installation. This paper will be of background interest to someone desiring a brief look at one version of simulation analysis.

R70-15058 ASQC 830; 813
RELIABILITY FACTORS IN THE DESIGN PROCESS
E. D. Karmiol and S. N. Greenberg (General Electric Co., Re-Entry and Environment Systems Div., Philadelphia, Penna) *In: Proceedings of the 1970 Annual Symposium on Reliability, Los Angeles, Feb. 3–5, 1970* Symposium sponsored by the Institute of Electrical and Electronics Engineers, Institute of Environmental Sciences, American Society for Nondestructive Testing, American Society for Quality Control New York IEEE, Inc. 1970 p 146–155 8 refs

As an aid to the design engineer in monitoring his progress during the assignment period, a design and development stage system is presented. The various stages are defined; within each of the stages, the task elements particularly related to the reliability discipline are identified. Each of these reliability-related task elements are described, and the process by which it implements and/or supplements the design and development optimization is portrayed. Author

Review: This paper describes the role of reliability activities during the design phase. These activities are broken down into discrete steps which parallel the design effort and are discussed independently. Examples of their implementation and impact are given. The convergence of the design to an overall configuration with inherent high reliability is indicated. The paper is essentially documentary in that it alludes to a particular reliability implementation; however, the basic structure of the technique could be of interest to a wide class of readers. There are no definite concluding remarks; but selected literature is cited for further reading. The paper is fairly clear, but there is difficulty with some of the abbreviations (e.g., "ROM" was defined parenthetically in Table I). The first author in a private communication has pointed out that the paper was presented in a tutorial session. Thus, its content was restricted to a description of proven reliability techniques together with an indication of their usefulness in the design process. The authors felt that further discussion of alternatives and additional concluding remarks would not be germane to their purpose.

84 METHODS OF RELIABILITY ANALYSIS

R70-15013 ASQC 844; 824
A NOTE ON THE SHEAR STRESS CRITERION FOR FATIGUE FAILURE UNDER COMBINED STRESS
R. E. Little (University of Michigan, Ann Arbor, Mich.) *Aeronautical Quarterly,* vol. 20 Feb. 1969 p 57-60 3 refs
(A69-25140)

Nishihara's combined bending and torsion out-of-phase fatigue limit data are analyzed. The Tresca shear stress failure criterion predicts strengths up to 30% higher than observed. It thus appears that renewed attention should be given to the basic problem of developing reliable combined stress failure criteria. It is suggested that new test methods will be required for this purpose. Author (IAA)

Review: As we become more sophisticated in the reliability techniques we use, we demand a corresponding sophistication in the data that are available. This paper shows that as one tries to calculate the fatigue behavior of a part more closely, he requires not only more sophisticated data but better theory. The author is calling attention to the fact that neither the theory nor the data are available for making fatigue life calculations with multi-axial stresses. Those who will find this paper of interest include theoretically inclined mechanical and metallurgical designers, and researchers (both theoretical and experimental) in fatigue. The author is to be commended for showing the ways in which present data and theory are inadequate.

R70-15020 ASQC 844; 612
A COMPUTER PROGRAM FOR PARTS COUNT MTBF PREDICTION
J. T. Henderson (Gulton Industries, Inc., Data Systems Div., Albuquerque, N. Mex.) *Evaluation Engineering,* vol. 9, no. 1 Feb. 1970 p 28-29,41

A computer program is presented whereby a particular design can be analyzed for its mean time before failure (MTBF) in a matter of minutes. Furthermore, any possible combination of four environments and four levels of component screening are selectable. The program is easily modified and uses conversational mode. It does nothing that couldn't be done manually but it does offer time and cost savings over the manual approach of parts count MTBF predictions. Finally, it serves as an example of the type of programs that can be written for a time sharing system. Author

Review: The idea of this article is commendable; i.e., to have a simple, methodical approach for a parts count MTBF prediction using an uncomplicated computer program. Unfortunately, computer printouts and teletype often reproduce poorly; and the figures in the text are no exception. (There is an editorial error: apparently Figure 2 is Figure A and Figure 1 is Figure B.) The program was not checked by this reviewer, but it seems to be very short as the author has mentioned. He suggests that a different set of failure rates is a simple matter to input; that it may be, but as with all computer manipulations, one has to be very careful that the data are put in correctly since mistakes are very easy to make and often difficult to find. The matter of significant figures in these computations deserves some comment. In using generic failure rates, one is lucky to be within a factor of 2 since the detailed application is unknown, the manufacturer is unknown, and the quality control procedures are unknown. Therefore, it is somewhat disheartening to find a failure rate for carbon film resistors listed to five significant figures and many of the failure rates listed to an implied accuracy better than 1%. The accuracy of the answer as printed out is apparently given to machine accuracy and no effort was made to round it off before printout. In this situation, the answer too is likewise uncertain within a factor of at least two. While this is obvious to many people and undoubtedly to the author, it often helps if the printout in this kind of program were to remind the reader in some way of the uncertainty in the answer (the usual way is to limit the significant figures). Regardless of the above comments, the calculations often need to be made and the author's program provides a handy way to do them.

R70-15021 ASQC 844
WHEN ARE WELD DEFECTS REJECTABLE ? -PARTS 1 AND 2
Helmut Thielsch (Grinnell Corp., Research and Development Div., Providence, R.I.) *Conference on the Significance of Defects in Welds, 2nd, London, May 29-30, 1968, Paper* 20 p *Materials Evaluation,* vol. 22, no. 2 and 3 Feb. and Mar. 1969 p 25-33

and 49-59 4 refs
(A69-19696; A69-23372)

The qualification criteria of weld defects are discussed, with special attention paid to defining harmful and harmless weld defects. The concept of judgment is stressed, and it is pointed out that by taking judgment away from the engineers, inspectors, welders, metallurgists, and even designers a critical and important aspect of their responsibility is eliminated. Common weld defects, such as cracks, lack of penetration, incomplete fusion, and slag defects, are discussed in this context. The importance of procedure judgment in porosity problems is emphasized, with consideration given to such topics as entrapped weld spatter, undercut, concavity, centerline crevice, mismatch, dissimilar metal welds, metallurgical orientation, stresses, and failures. The welding process and welding procedure variables are examined, and factors to be taken into account in the training of welding and inspection personnel are cited. M.G.J.

Review: This is an excellent set of papers; it should be at least scanned by everyone concerned with nondestructive evaluation (NDE) and it should be studied by those who are concerned with NDE of metals. The topic of "when is a deviation from idealness considered to be a defect" is receiving much more attention now in the literature and deserves even more than it is getting. This author treats not only places where welds are rejected unnecessarily but goes on to show in illustrated detail the kinds of defects that ought to be causes for rejection. Unfortunately, implementing the author's recommendations will be difficult because it requires everybody in the cycle to be both more knowledgeable and more conscientious. This will be just as difficult for the specification and standards writers as it will for welders and inspectors. Even though some engineers may disagree with a few of the author's detailed examples, there can be little doubt as to the validity of his general thesis. Another paper on this same topic and with a similar message is covered by R70-14954.

R70-15024 ASQC 844; 775
MAGNETIC PERTURBATION INSPECTION TO IMPROVE RELIABILITY OF HIGH STRENGTH STEEL COMPONENTS
John R. Barton and Felix N. Kusenberger (Southwest Research Institute, Instrumentation Research Dept., San Antonio, Tex.) *Conference of the Design Engineering Division of the American Society of Mechanical Engineers, New York, May 5-8, 1969, Paper* 12 p refs

The significant role that microscopic inclusions, approximately 0.001 in. in diameter, play in the development of fatigue damage of high strength steels is established. Examples showing detection of such flaws by magnetic perturbation inspection, and also the detection of fatigue damage, minute cracks, initiated at these flaws are presented. Results substantiate that mechanical removal of early fatigue cracks permits continued stress cycling far beyond the point at which failure would have occurred if the fatigue damage had not been removed. Statistical and individual comparisons of specimen lives are made relative to published data, and interesting aspects of these comparisons are discussed. Author

Review: The discussion is limited to high-strength steels rather than being true for steels in general. Oldtimers will find it hard to realize that inclusions 1 mil in diameter have been located and the specimen sectioned at the precise point so that metallurgical preparations will show exactly that inclusion. They would also be strongly interested in the extension of specimen life by local removal of fatigue cracks as verified by subsequent long-duration stress cycling. As noted, this is very likely to be true of the removal of surface and near-surface inclusions. Conceivably this concept of defect removal could provide a valid method for extending the useful life of expensive and critical components. The results are amazing, but the work appears carefully documented. At an earlier time, it was probably just as difficult to comprehend that a Liberty ship had cracked in two because of the defect caused by a weld-strike mark. This work is important not only in its own right in improving the reliability of high-strength steels, but also in alerting designers. When high-strength steels are specified the designer must be extremely careful about defects which are introduced during the manufacturing process, and he must be very careful to be sure he has considered the many failure modes and mechanisms inherent in high-strength steels. Thus, this paper makes good reading for a great variety of people all of whose interests converge in creating reliable steel products.

R70-15027 ASQC 844
ANALYSIS OF FAILURES
Charles Lipson (Univ. of Michigan, Ann Arbor, Mich.) *Mid-Year Meeting of the Society of Automotive Engineers, Chicago, May 19-23, 1969, Paper* 16 p

Failures of machine components are described, systematized, and analyzed. An attempt is made to trace the causes of each failure, describe the mechanism, list the influencing factors, and suggest the remedies. A meaningful analysis of a failed part is one of the most useful sources of information available to the engineer. From the study of failure he can frequently learn whether the failure was caused by a defective design, inadequate material properties, poor production practice, or service abuse, and can thereby devise necessary improvements to eliminate failure. Author

Review: This author enjoys a good reputation for his articles on this topic, and readers of this paper will not be disappointed. The literature seems to be filled with papers on failure modes and mechanisms for mechanical parts (and this paper is limited to metal parts), and yet the classifications shown in this paper demonstrate that the designer, if he had paid proper attention to detail, could have redesigned the part so that it would not have failed. This paper has a very practical orientation and there is little abstract theory in it. It is the kind of paper which mechanical designers should review. If they run across something new, then they should study it. One thing that it sometimes helps to remember is that it is always the material that fails. The question is: Who was in the best position to do something about it? In an efficient design, the material is as uniformly stressed as is feasible. Too much stress in one particular place is a black mark against the designer because the part is too likely to fail from the stress concentration, and likewise, too little stress in another place means that perhaps there should have been less material there.

R70-15029 ASQC 844
RATING LIFE OF A LINEAR MOTION ASSEMBLY
J. P. Hyer and T. A. Harris (SKF Industries, Inc., King of Prussia, Pa.) *Lubrication Symposium, San Francisco, June 16–1969, Paper* 5 p refs *Mechanical Engineering* Oct. 1969 5 refs

The linear motion assembly is a type of rolling bearing used to support and guide a translating member along a round shaftway. The load-carrying adequacy of this bearing for a given application is evaluated in the same way as for conventional rolling bearings by determining a statistical fatigue life. This paper presents an analytical development of the equations for dynamic capacity from which fatigue life can be calculated. Contact deflection and the effects of preload are also examined. Author

Review: This is an example of attention to detail in calculating the life of a mechanical component. The paper shows that, in general, engineers make use of the more simple formulas they have available to them rather than extremely complicated ones. For example, the exponent in the load-life equation is chosen as three even though it is considered to lie somewhere in a range about this number; it is likewise presumed that the shaftway bearing and ball bearings have the same Weibull slope. This paper is a good example for designers. It is uncomplicated, short and easy to understand. It is the kind of calculation which many designers ought to be making (to improve reliability) and yet are not.

R70-15031 ASQC 844; 771

National Aeronautics and Space Administration. Goddard Space Flight Center, Greenbelt, Md.

SOUNDING ROCKET PARAMETERS VERSUS FLIGHT RELIABILITY

Brian C. Pierman Mar. 1969 16 p ref Submitted for publication

(N69-27776; NASA-TM-X-63558; X-326-69-162) Avail: CFSTI

The physical parameters of sounding rockets, flight weight, and number of telemetry channels were compared to flight failure rates for the purpose of developing a basis for the selection of environmental tests to be applied to sounding rocket payloads. Correlation between greater weight and decreased flight success is established, while no correlation is established between telemetry channels and flight success. Author

Review: The idea behind this investigation was good. The statistical methods chosen to investigate the weight vs. reliability correlation are not easily interpretable, especially by the non-statistician. There was a tremendous amount of scatter in the data, and conclusions are difficult to draw. The conclusion of the author is safe, however, that the heavier payloads be given extra consideration for more reliability tests. With the results of so many missions available, it might be possible to make a more detailed analysis to see what other reliability factors could be uncovered.

R70-15033 ASQC 844

ENGINE FAILURE FINGERPRINTS

N. J. Musil (TRW, Inc., Cleveland, Ohio) [1969] 9 p refs

The importance of diagnosing failures to prevent a recurrence is pointed out. Emphasis is placed on looking for the tell-tale markings and clues that will aid in tracing the cause of various engine parts failures; also, on the inspection of used parts and the selection of new parts. It is also pointed out that the selection of premium replacement parts may be necessary under certain operating conditions. Author

Review: This is another paper which shows that the analysis of a failed part can sometimes show wherein some other part of the system may have been malfunctioning and have contributed to the failure; that is, many failures are secondary failures caused by poor performance of some other part. This is perhaps more true in mechanical systems than electronic ones, and this paper is devoted to mechanical systems (in particular, to the gasoline internal combustion engine). This paper is worthwhile reading even for those not directly concerned with the reliability of gasoline engines because the types of things described in it are useful in many other areas as well. The idea is to do some thinking backwards as to what other malfunctioning subsystem could have caused the observed results. This message is directed more toward the mechanics who are repairing these failures rather than the engineers who are designing the system, but the message may have to reach the mechanics via a circuitous route. The reliability of virtually all mechanical equipment depends on the quality of the maintenance that is performed on it. This is an area which reliability engineers have sometimes overlooked, or have been prone to anoint with sophisticated names such as maintainability physics instead of using the straightforward approach in this paper which is more direct and more helpful.

R70-15035 ASQC 844

RELIABILITY OF CONTROLLED COLLAPSE INTERCONNECTIONS

K. C. Norris and A. H. Landzberg (International Business Machines Corp., Components Division Lab., Poughkeepsie, N.Y.) *IBM Journal of Research and Development,* vol. 13, no. 3 May 1969 p 266–271 10 refs

The use of solder pads to join multi-pad integrated circuits chips to modules provides a highly reliable, rugged interconnection technology. This paper reports some important aspects of the reliability evaluation that was carried out on the "controlled chip collapse" interconnection system developed by IBM. Included are an analysis of the mechanics of the system, a model to establish the relationship among different thermal fatigue testing conditions, and experimental verification of the model. In the course of this work, the chip failure rate of the interconnection as used in present designs was predicted to be better than 10–7%/1000 hours for the mechanism studied. Author

Review: This paper is a good example of applying reliability physics to a problem in microcircuits. It shows also that electronics engineers must be familiar with the principles of mechanical failure, especially fatigue, at least in sufficient depth to be able to recognize the problem and know where to go for help. The analysis uses appropriate approximations in the form of some rather simple models, but these are usually quite sufficient for several reasons: (1) the available experimental data rarely justify more complex models, (2) the more complex ones are extremely difficult to handle and analyze, and (3) the results given by a more simple analysis are virtually always quite sufficient. Reliability engineers can find two kinds of value in this paper: (1) the same failure mechanism can arise in many circuits and thus reliability engineers should be familiar with this analysis of it, and (2) the principles involved are applicable to a much wider range of circumstances and this paper is a good exposition of them.

R70-15036 ASQC 844

Royal Aircraft Establishment, Farnborough (England).

ESTIMATION OF THE RELIABILITY OF FATIGUE LOADED STRUCTURAL COMPONENTS [BEURTEILUNG DER ZUVERLAESSIGKEIT SCHWINGBEANSPRUCHTER BAUTEILE]

E. Haibach Aug. 1968 21 p refs Transl. into ENGLISH from Sonderdruck Aus Luftfahrttech. Raumfahrttech. (West Ger.) issue 13, no. 8, 1967 p 188–193

(N69-21125; RAE-Lib-Trans-1314) Avail: CFSTI

Proceeding from the scatter distribution of the allowable fatigue loads and the scatter distribution of the actual working loading, the probability of failure of fatigue loaded structural components can be determined for every given value of the service life, and thus a measure of the component's reliability found. The traditional, usually empirically determined, safety factor is now found as a statistically based safety range dependent on the particular failure probability. The analysis first of all sets out to explain

the principal features of the concept involved. Finally, difficulties which may arise in practical cases are considered, and by means of a simplified calculation of the failure probability a way out of these difficulties is indicated. Author

Review: This paper is not too clearly written (or is poorly translated), but is a contribution to the theory of random fatigue. The author has an interesting approach to a safety factor. He considers the uncertainties in the structural properties as well as in the loading. It will be worth the effort to read and understand the paper, at least for those doing research in fatigue.

R70-15039 ASQC 844

ITT Semiconductor Products Labs., Palo Alto, Calif.

RELIABILITY PHYSICS STUDIES ON TRANSISTORS FINAL TECHNICAL REPORT, PERIOD ENDING 20 MAR. 1967

R. M. Scarlett and Grant C. Riddle Griffiss AFB, N.Y. RADC 1 Sep. 1967 104 p refs

(Contract AF 30(602)-3975)

(N70-72340; RADC-TR-67-174; AD-821392)

Section 1 deals with the general theory of lateral instability and electric test methods for detecting it. A general model is set up, from which the criterion for stability can be determined under various conditions. It is shown that at high collector voltage an electrical instability exists which is much faster than the thermal instability occurring at lower voltages. Emitter resistance can be effective in stabilizing against both types of instability provided the emitter is divided into small enough domains, each with an independent resistance. These domains may be as small as 5 u in lateral dimension. A new and convenient electrical test for determining the onset of instability is described. A comparison of this test with previously used pulse tests shows that the stability index pulse test is the most conservative in predicting the onset of the hot spot formation which precedes second breakdown. An experimental study of second breakdown at high collector voltage supports the electrical instability model. Section 2 describes work done to find a material suitable for a distributed emitter resistor. Both evaporated mixtures and reactions induced by heating suitable combinations of materials on the chip were considered. In the former category, chromium–germanium and aluminum–aluminum oxide co-evaporated mixtures produced stable films up to about 1/100 ohm cm. The required 1–10 ohm-cm could not be obtained stably. In the latter category, resistive material produced by reacting Al with Si O2 and by oxidizing nickel films were investigated. Neither of these proved satisfactory. TAB

Review: This report begins with a useful review of previous second-breakdown findings (by the same organization) in an attempt to define clearly the additional contribution contained in the new report which is the final report of the fifth contract in a series dating back to 1962. The new contribution consists of refinements in previously discussed ideas, the introduction of an electrical instability over and above the previously described thermal instabilities and the development of dc tests for heralding the approach of second breakdown. (Previously a pulse test was used to measure a thermal stability index.) The well-known technique of dividing the emitter region into a large number of independent parallel regions, each with a series resistor to help equalize the current flow over the total emitter area, is still felt to be effective in stabilizing the performance of power transistors. The second part of this report describes efforts to develop a sandwich resistor technology in which a thin-film resistor is inserted between the emitter metal contact and the emitter diffused region, forming an MRS structure analogous to the familiar MOS or MIS structure. The requirements on the thin resistive film that constitutes the "R" between the metal and the silicon are severe and the authors report here that they have not been successful at developing a completely adequate method for building this resistor. Although the report is now over two years old (but only recently released for unrestricted distribution), no new publication has been uncovered to show that this particular thin-film sandwich approach has been more fruitful since then. The report is complete and reflects detailed analysis and understanding of current distribution and flow in power transistors.

R70-15045 ASQC 844

ELECTROMIGRATION FAILURE MODES IN ALUMINUM METALLIZATION FOR SEMICONDUCTOR DEVICES

James R. Black (Motorola, Inc., Semiconductor Products Div., Phoenix, Ariz.) *Proceedings of the IEEE*, vol. 57, no. 9 Research sponsored in part by the Air Force Sep. 1969 p 1587-1594

(Contract F30602-67-C-0166)

Two wear-out type failure modes involving aluminum metallization for semiconductor devices are described. Both modes involve mass transport by momentum exchange between conducting electrons and metal ions. The first failure mode is the formation of an electrically open circuit due to the condensation of vacancies in the aluminum to form voids. The second is the formation of etch pits into silicon by the dissolution of silicon into aluminum, and the transport of the solute ions down the aluminum conductor away from the silicon–aluminum interface by electron wind forces. The process continues until an etch pit grows into the silicon to a depth sufficient to short out an underlying junction. Author

Review: This paper is a readable, well-illustrated description of electromigration phenomena and the problems they can cause in the aluminum metallization films common to integrated circuits. While much of this paper is a repeat of previously published ideas and illustrations (see, for example, a paper by the same author in *IEEE Transactions on Electron Devices, ED-16*, 338, April 1969), an additional failure mechanism is discussed here in which silicon atoms, dissolved in the aluminum metallization, also migrate under the influence of the electron wind. Figure 2 is a key figure; it plots median-time-to-failure for aluminum films as a function of reciprocal temperature and does this for three types of aluminum films: (1) films deposited on a cold substrate; (2) films deposited on a heated substrate, and (3) films deposited on a heated substrate and overcoated with SiO_2. Below approximately 275° C this figure shows dramatic differences in the median-time-to-failure for the three films and the author suggests that the value of activation energy deduced from a plot such as this is a measure of film quality. The data make it clear that evaporation of aluminum on a heated substrate followed by an overcoat of silicon dioxide is a superior metallization scheme insofar as electromigration goes. The author interprets his results to mean that the large crystal films (those deposited on a hot substrate) have less grain boundary diffusion than do the small crystal films (those deposited onto a cold substrate) and that the further resistance to electromigration failures exhibited by those films deposited on a heated substrate and overcoated with silicon dioxide demonstrates that surface diffusion plays an important role in electromigration failures. This last conclusion has been challenged by Blech and Meieran (*1970 Annual Symposium on Reliability*, pp. 243–248) and seems to conflict with electromigration failure data on single-crystal aluminum films (see d'Heurle and Ames, Appl. Phys. Ltrs. *16*, 80, 1970). Blech and Meieran also question the model employed here to deduce activation energies—the activation energy is measured on a plot whose ordinate contains the square of the inverse of current density. In spite of these objections to the interpretation of the data, the information contained in Figure 2 is very useful and pos-

sesses the virtue of being easily measured and easily read. The reader can readily see the safe design regions for aluminum intraconnects and can, if he wishes, incorporate his own uncertainty factor in the light of the questions that have been raised.

R70-15046 ASQC 844

VOID FORMATION FAILURE MECHANISMS IN INTEGRATED CIRCUITS

Bernard Selikson (Lowell Technological Institute, Lowell, Mass. and General Electric Company, Syracuse, N.Y.) *Proceedings of the IEEE*, vol. 57, no. 9 Sep. 1969 p 1594–1598 34 refs

The several interfacial regions where voids and electrical opens occur in semiconductor discrete devices and monolithic integrated circuits are described. The metals used at these interfaces in circuits today are listed and a description is given of the void producing mechanisms applicable to each area, along with techniques for their detection. Voids which develop in the bond of gold wire, which is ball bonded to aluminum metalization as a result of intermetallic purple plague formation, are explained as an example of the Kirkendall effect. However, the faster diffusion of one of the metals of a bond producing voids cannot explain the observation of voids in both the gold and the aluminum side of the bond. Recent thin film experiments account for this effect by a process which is rate limited by diffusion through the newly formed intermetallic phase. Analysis of five newer alternate metalization systems for circuits show them all to have the potential for compound formation, which may be expected to be accompanied by void formation. Author

Review: Metallization problems have been recognized as a major source of silicon device failure for at least eight years (see R64-11508, R65-12003, R66-12682, R67-13357, R67-13360, R67-13363, R67-13392, R68-14073, and R68-14075). While it is generally agreed that the major failure mechanism is the formation of voids which inevitably accompany the diffusion of one metal into an adjoining metal, this paper makes it clear that existing knowledge is by no means exhaustive or adequate to enable complete understanding of the physics involved. Sufficient experience exists to know what conditions the common aluminum–gold bond can withstand without contributing to failure, but the roles of surface diffusion and diffusion in intermetallic compounds are not sufficiently well known to enable the prediction of the outcome of even simple bimetallic diffusion experiments. The author illustrates this beautifully by a simple experiment with a glass microscope slide, one half of which is coated with aluminum and the other half coated with gold. The two films have a narrow overlap band in the center of the slide. This structure constitutes a test vehicle for observing the diffusion of gold into aluminum and vice versa. Present understanding of this phenomenon is insufficient to predict the results that the author observes in even this simplest of experiments. Consequently, although intermetallic diffusion and metallization failures have been studied extensively and intensively and much insight and practical understanding have been acquired, the problem is not completely solved. This message is a key point of the author's paper, although not explicitly stated. A second point, which is explicitly stated, is that void formation is not unique to the well studied and much maligned aluminum–gold system, but exists in all multimetallization schemes. The difference is one of degree and while gold–aluminum has very low tolerance to time-temperature stress, other multimetal systems are never completely free of it. A third significant point is the emphasis placed on the role of diffusion through an intermetallic phase, a generally ignored consideration heretofore. If, in a binary system, solid state diffusion results in the formation of intermetallic compounds, the further reaction between these two constituents will depend upon the diffusion rate of these constituents in the already formed intermetallic compound. The difference between a protective and a non-protective compound has far-reaching practical consequences.

R70-15047 ASQC 844

Army Materiel Systems Analysis Agency, Aberdeen Proving Ground, Md.

ON THE IMPROVEMENT OF ELECTRONIC EQUIPMENT RELIABILITY

Keats A. Pullen, Jr. Apr. 1969 30 p

(N69-33285; AD-687290; AMSAA-TR-20) Avail: CFSTI

The reliability of certain airborne military electronic equipment in terms of measured mean time between failures (MTBF) has recently been shown to be between 3.5 and 6 hours. Reliability in this sense is usually based on actual measurement of time between failures rather than a statistical probability of failure occurring for a given period based on number of components. Improvement of reliability in this sense is based on a determination of the nature of the principal causes of failure and placement of them in the order of their descending probability of occurrence. Based on this ordering, one can often find ways of reducing the probability of occurrence on the causes of failure to the point where they can be considered to be random. Much of the control required for the high-probability causes of failure of electronics can be developed at the network design stage, since the electronic failure problem is frequently associated with either design difficulties or conditions of excessive heat in the environment. Particular emphasis is placed on data presentation herein, since experience has shown designers do work with inadequate information, a major part of the problem can be traced to inadequacies in characterization of components and devices, leading to excessive dissipation and excessive supply voltages. Further problems encountered as a consequence of the effect of a severe environment on a marginal design are discussed, and some ways of finding make-do fixes are described.

Author (TAB)

Review: This paper begins dramatically–"the mean time between failure (MTBF) values being obtained for airborne fire control systems of between 3.5 and 6 hours in a subtropical environment is costing us both lives and equipment." Misuse of components and inadequate circuit design, both due to inadequate knowledge of component properties, are declared to be a leading cause of the present poor performance of complex military electronic systems. The author covers a broad range of topics in amplifying his conclusions and in recommending solutions. He discusses transistor modeling, circuit design, and cooling of aircraft electronic equipment. Because the spectrum covered is quite broad, the treatment is unavoidably cursory. For example, the author states that components such as transistors are not properly characterized by the manufacturer and therefore a user can really know his component only through experience. He cites the absence of the parameter m from all transistor descriptions. He does not define m in this paper; however, he has stated in a private communication that it is defined in another report (SEEC Series, Vol. 4, p. 20). It would also have been helpful to have some indication of its possible importance. What is not stated is that for this parameter to be of significance, the transistor must be so designed that emitter crowding and other ohmic drops in the base region are less important than the non-ohmic drops of which parameter m is a measure. In practice, it turns out to be extremely difficult to find a transistor built and used in which m is of practical value. Another consideration with respect to the author's treatment of the subject of component specifications is the omission of discussion pertaining to attempts to characterize the behavior of transistors and other components in circuits by such computer programs as ECAP, CIRCUS, and SCEPTRE. While it is known that the programs have some inadequacies, the reviewer

feels that these previous attempts at transistor modeling should at least be considered by anyone attacking this phase of contemporary electronic technology. In ECAP, for example, the Ebers-Moll model of a transistor is used with some 38 independent parameters to characterize a given transistor's performance. This information clearly is much more than that which one would read from a manufacturer's specification sheet (which, of course, is a disadvantage for reliability purposes because the manufacturer does not guarantee many of the parameters used in the model). Many users feel that the information used in ECAP is adequate to permit detailed evaluation of a circuit before it is actually built. The author has identified a very real problem but his ideas for its solution need further consideration and work. Even though Section III, Thermal Conditions, is general and brief, the ideas have merit.

R70-15056 ASQC 844
ANALYZING AND INTERPRETING FIELD FAILURE DATA
Richard F. Powell (H. H. Scott, Inc., Maynard, Mass.) *In: Proceedings of the 1970 Annual Symposium on Reliability, Los Angeles, Feb. 3–5, 1970* Symposium sponsored by the Institute of Electrical and Electronics Engineers, Institute of Environmental Sciences, American Society for Nondestructive Testing, American Society for Quality Control New York IEEE, Inc. 1970 p 94-100 3 refs

Sources of field failure data are reviewed, and techniques of data collection applicable to the consumer electronics industry are discussed. It is pointed out that the mechanism for obtaining these data must be consistently operated and the data, once collected, must be analyzed and interpreted to be of use. The question of determining the true field failure rate is explored in some depth with a simple mathematical analysis, and a comparison is made of the results of this analysis with some actual field failure data. Author

Review: This paper does two things: (1) points out that field failure data are difficult but necessary to interpret, and (2) provides some models for estimating a field failure rate. One consideration about the inadequacy of failure reporting during warranty is that some dealers falsify such records for a variety of reasons, e.g., to recoup losses on labor. The formulas deal with various methods of taking into account the delay between the manufacture of a product and its being put into service by a customer. Great care must be exercised in the use of these models since they contain adjustable parameters; the values chosen for those parameters greatly determine the answers that one gets for the field hazard rate and whether it is increasing or decreasing. (This point is not unique to the present paper; it is also a property of other proposals for taking the delay into account.) For those who are concerned with making the best use of field failure data, there are some good points in this paper. This is not an area in which a great deal has been published, and the need for understanding is great. Many of the problems in a consumer industry are similar to those in military or space use, especially those smaller items which are used in relatively large quantities. The government has not solved the problem either. Unfortunately, in that area, there are a great number of papers each year which present another new and final solution to the problem.

R70-15059 ASQC 840; 864
A SYSTEM FOR REPORTING AND ANALYZING PRODUCT ASSURANCE DATA
E. F. Jahr (IBM Electronics Systems Center, Owego, N.Y.) *In: Proceedings of the 1970 Annual Symposium on Reliability, Los Angeles, Feb. 3–5, 1970* Symposium sponsored by the Institute of Electrical and Electronics Engineers, Institute of Environmental Sciences, American Society for Nondestructive Testing, American Society for Quality Control New York IEEE, Inc. 1970 p 173–180

A system premised upon associating information from independent files, retaining flexibility to accommodate changes, is described for the handling of information pertaining to hardware rejections as they occur and are reported. The techniques discussed cover data describing symptoms, mechanisms, causes and origins of discrepancies reported from suppliers, in-plant test and inspection results, and field data. Remote terminal inputing and display capability expedites data processing and retrieval. Author

Review: This short but well-written discussion of a now-familiar topic is well worth reading even for the experienced practitioner of data reporting systems. The paper was intended to be tutorial in nature and accomplishes this purpose. While the paper contains no references, readers can locate many valuable documents in this subject area by referring to subject category 84 in RATR. A highlight of this paper is the author's description of a training program and a booklet developed to aid in the "sale" of the system to users. Another important aspect is that the author offers definitions which are generally in agreement with international and U.S. standards. This tutorial effort is highly recommended reading for reliability specialists.

85 DEMONSTRATION/MEASUREMENT

No abstracts in this issue.

86 FIELD/CONSUMER ACTIVITY

No abstracts in this issue.

87 MAINTAINABILITY

R70-15022 ASQC 871
MAINTENANCE OF A LARGE ELECTRONIC SWITCHING SYSTEM
S. H. Tsiang, George Haugk, and Howard N. Seckler (Bell Telephone Laboratories, Inc., Whippany, N.J.) *IEEE Transactions on Communication Technology*, vol. Com-17, no. 1 Feb. 1969 p 1-9 7 refs

This paper discusses maintenance considerations and field experience with the Bell System's No. 1 Electronic Switching System (No. 1 ESS). A brief introduction to the ESS includes a comparison with computers and a history of ESS development, which is followed by a discussion, in some technical depth, of particular

areas of ESS maintenance design and practice. One example is the use of dictionaries to isolate equipment faults. The effectiveness of the dictionaries is also discussed. Performance data of several types are presented for the central offices already in service.
Author

Review: This paper deals with reliability from both a hardware and a software point of view. The required degree of reliability is achieved with redundancy and automatic diagnostics. This paper is not too detailed, and further references are given. A few hardware difficulties are examined and some data on reliability of circuit boards are shown. In general, they are about 10^{-7} board replacements per hour per pack used in the system. Conventional discrete electronics are used; apparently no integrated circuits are involved. This paper offers not only a good description of the procedures being used in the electronic switching system (Bell Telephone), but gives a good picture of the kinds of maintenance and reliability activities that can be effectively carried on. There is a minimum of technical jargon so the paper can be understood readily by those who are not telephone or computer specialists.

R70-15042 ASQC 871; 814

MAKING AN EQUATION OF COST AND MAINTENANCE

Frede Ask (World-Wide Service Organization of Storno, Copenhagen, Denmark) *Electronics Weekly*, June 19, 1968 4 refs

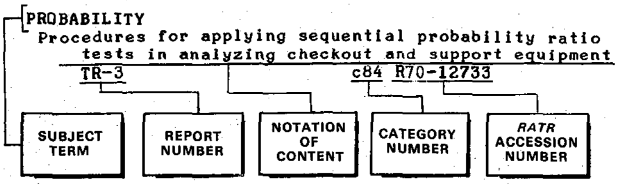
A method of dimensioning is described for estimating the size of a service organization required for the maintenance of a given number of operational units of equipment. The technique is based on a mathematical system which has been used in telephone systems for calculating the waiting time on subscriber calls. The approach uses the waiting time theory for exponentially distributed lengths of calls, and a loss formula which is a special form of Poisson's distribution. The point is made that the uncertainties inherent in calculating the maintenance of electronic equipment make the use of more sophisticated mathematical systems unnecessary.
M.G.J.

Review: This paper gives an approximate method for estimating the size of a maintenance shop, given a knowledge of the hazard and repair rates of the equipment, and the waiting time. All times are presumed exponentially distributed. The author makes the good point that while more complicated equations are possible, the available data to be used in evaluating them are so uncertain that the extra sophistication is wasted. This is a good point because too often in the literature people mistake mathematical sophistication, model completeness, and arithmetic precision for accuracy of description of the real world. There are occasional editorial lapses, apparently due to the language problem (English is not the author's native language), but the examples make the discussion easy to follow so that the results of the paper are accessible to virtually anyone who has need for them.

SUBJECT INDEX

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS VOLUME 10 NUMBER 5

Typical Subject Index Listing



The Notation of Content, rather than the title, is used to provide a more exact description of the subject matter. The category number and *RATR* accession number are used to locate the abstract-review appearing in the abstract section of *RATR*.

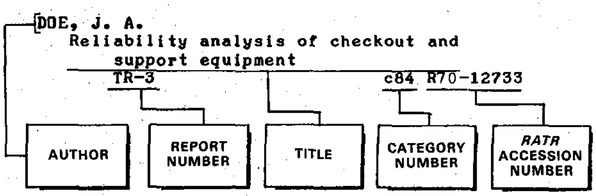
A

C

D

PERSONAL AUTHOR INDEX

Typical Personal Author Index Listing



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REPORT AND CODE INDEX

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS VOLUME 10 NUMBER 5

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This may be used to identify the *RATR* accession number of reports covered in this journal. To the right of each report number is the *RATR* accession number preceded by the category number for locating the abstract-review in the abstract section of *RATR*. For purposes of this index, AD, N, and A numbers (accession numbers from *TAB, STAR,* and *IAA,* respectively) and ASQC code numbers are treated as "report" numbers. Thus, the section of this index listing ASQC codes may be used to identify the *RATR* accession number of the coded abstract-reviews appearing in *RATR.*

ACCESSION NUMBER INDEX

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS VOLUME 10 NUMBER 5

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This list of *RATR* accession numbers may be used to identify the category in which a numbered abstract-review appears in the abstract section of this journal. Accession numbers are arranged in ascending order. Preceding each accession number is the category number for locating the abstract-review in the abstract section of *RATR*.

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Reliability Abstracts and Technical Reviews

JUNE 1970

Volume 10
Number 6

R70-15060—R70-15108

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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The second section of *RATR* contains four indexes: The Subject Index is to assist in scanning or searching the literature on specific topics. The Personal Author Index identifies the publications of specific authors. The Report and Code Index is a listing of the report numbers of items abstracted and reviewed in the journal; this index also includes a listing of the ASQC codes for identifying the *RATR* accession numbers of the items to which the codes have been assigned. The Accession Number Index identifies the categories in which the abstract-reviews appear in the journal. Cumulative indexes are published annually.

EXAMPLES OF CITATIONS IN *RATR*

***RATR* ACCESSION NUMBER** — R70-12733 — ASQC 844; 413 — **ASQC CODES**

CORPORATE SOURCE — General Equipment Company, Banville, Calif.

TITLE — **RELIABILITY ANALYSIS OF CHECKOUT AND SUPPORT EQUIPMENT**

AUTHOR — John A. Doe 23 Sep. 1969 (**PUBLICATION DATE**) 27 p refs

CONTRACT OR GRANT — (Contract NAS15-13411)

REPORT NUMBER — (AD-629305; N69-15098 (***TAB* AND *STAR* ACCESSION NUMBERS**); TR-3) Avail: CFSTI (**SALES AGENCY AND PRICE**)

***RATR* ACCESSION NUMBER** — R70-12739 — ASQC 814 — **ASQC CODE**

TITLE — **SEMICONDUCTOR RELIABILITY**

AUTHOR AND AFFILIATION — Joseph A. Smith (Eastern University, Arlington, Penn.)

JOURNAL REFERENCE — *Electric Journal,* vol. 8, Apr. 1969, p 478–492.

***IAA* ACCESSION NUMBER** — (A69-12569)

***RATR* ACCESSION NUMBER** — R70-12765 — ASQC 773; 221; 823 — **ASQC CODES**

TITLE — **TESTS OF SYSTEMS WITH SOME DEPENDENT FAILURES**

AUTHORS AND AFFILIATIONS — Joseph A. Smith (Eastern University, Arlington, Penn.) and B. James White (General Equipment Company, Banville, Calif.)

CONFERENCE OR SYMPOSIUM REFERENCE — *Association of Reliability Engineering, Failure Rate Conference, Olney, Tex., Mar. 13–17, 1969, 8 p.* Available from Assoc. of Reliability Eng., New York: $1.00 (**AVAILABILITY AND PRICE**)

***IAA* ACCESSION NUMBER** — (A69-12407)

VOLUME 10 NUMBER 6

Reliability Abstracts and Technical Reviews

A Monthly Publication

of the National Aeronautics and Space Administration

June 1970

80 RELIABILITY

No abstracts in this issue.

81 MANAGEMENT OF RELIABILITY FUNCTION

R70-15060 ASQC 813

DETERMINING OPTIMUM RELIABILITY PROGRAMS

Irving Doshay (Aerojet-General Corp., Azusa, Calif.) *In: Proceedings of the 1970 Annual Symposium on Reliability, Los Angeles, Feb. 3-5, 1970* Symposium sponsored by the Institute of Electrical and Electronics Engineers, Institute of Environmental Sciences, American Society for Nondestructive Testing, and American Society for Quality Control New York IEEE, Inc. 1970 p 43-54 11 refs

An approach is suggested whereby a reliability program is considered as a control system. Considering the reasonable alternate configurations of reliability control systems, tradeoffs may be made to establish the most desirable system. Cost considerations are given primary emphasis in the decision factors related to the analysis methods selections. Using the results of the tradeoffs or suboptimizations, an optimization technique is applied to establish the most desirable configuration. Calculations of typical transfer function values were made for varying periods after fabrication for each of four typical reliability control systems covering a range of program types. Such analysis provides a method for suboptimization of the competitive control systems. It includes the basic operations of design, fabrication, and field use, and then adds the sources of evaluation and feedback to provide the control functions for these operations. Author

Review: The twelve pages of this paper are jammed with a detailed summary of Reliability tasks, their relative complexities and values. It is recommended as excellent reading for managerial personnel involved with projects, Reliability, and Quality Control. The presentation is complete and well written. Free use is made of the cited references, none of which are among the author's many previously-published papers. Each topic discussed is associated directly with the announced intent of the paper: how to determine optimum reliability program content. The author offers some ratios of costs for various elements of a reliability program in terms of the system cost and also includes elapsed time for achieving a system with 95% reliability in terms of dollars per 100 units. These are supported by success ratios and life cycle costs. He also presents a set of values related to frequently used concepts of reliability which can be used as guides for managerial control of reliability functions. No indication is given as to the validity of the costs, but the reviewer is unaware of anything in the literature to challenge them. The author's estimates may be the first of what might be expected in the future. It is important to confirm or adjust these data so that the value of this contribution can be dynamic rather than static. The author in a private communication has commented as follows. "These concepts are evaluated in terms of a transfer function for each, which is calculated through the use of the equivalent signal flow graph for each described control system. Relative costs are also evaluated for each system, based on the author's summations of 'typical' costs for failure losses and reliability controls." One could disagree with the details of many points in the paper, but it is worth reading and the ideas worth adapting to the reader's situation.

R70-15064 ASQC 815

SPECIFICATION X-1414: A RELIABILITY MILESTONE

Lee H. Isaacson (Veterans Administration, Washington, D.C.) and Ervin F. Taylor (General Electric Co., Philadelphia, Pa.) *In: Proceedings of the 1970 Annual Symposium on Reliability, Los Angeles, Feb. 3-5, 1970* Symposium sponsored by the Institute of Electrical and Electronics Engineers, Institute of Environmental Sciences, American Society for Nondestructive Testing, and American Society for Quality Control New York IEEE, Inc. 1970 p 111-113

Recognizing that a medical equipment reliability problem exists, the Veterans Administration undertook the preparation of Specification X-1414 for biomedical monitoring systems. Included are a description of reliability of medical equipment, a brief history of Specification X-1414, a discussion of the comments to drafts of the specification, an assessment of the continuing problem areas, and a prognosis for the future of medical equipment reliability. Author

Review: The reliability effort described in this paper must be viewed in the perspective of "what is the best we can do right now," and in that sense it is hard to argue with the slant taken by the specification. Eventually, of course, one would like to see some quantitative reliability requirements included. There also needs to be some means of educating those manufacturers who are not aware of good reliability and quality practices. While there is a natural desire of industry to be left alone and told only about the end results, sometimes the quality and reliability cannot be effectively determined when looking only at the end product. Thus, the needs of the customer are as important as the desires of the manufacturer. Regardless of any of these other considerations, the important fact is that the V.A. has done *something* even

though it may not have been the best possible thing to do under all possible circumstances. If they can keep up the effort by improving the specification, they will be doing the best that can be expected of them, and they should be given every encouragement in this regard.

R70-15075 ASQC 810

PRODUCT AND PROCESS: THE SIAMESE TWINS

William H. Rombach (Precision Instrument Co., Palo Alto, Calif.) *In: Proceedings of the 1970 Annual Symposium on Reliability, Los Angeles, Feb. 3-5, 1970* Symposium sponsored by the Institute of Electrical and Electronics Engineers, Institute of Environmental Sciences, American Society for Nondestructive Testing, and American Society for Quality Control New York IEEE, Inc. 1970 p 156-161

The point is made that neither product reliability nor product producibility is achievable without process reliability. The importance of close interdependence between design engineering, manufacturing engineering, and product assurance is emphasized. The close similarities and major differences between the reliability and quality assurance disciplines are delineated, and it is proposed that these two functions be combined under the same functional management. Several positive approaches are suggested to enhance the reliability engineer's effectiveness in being a profit contributor. A corporate management overview is presented of what is required of reliability engineering or product assurance. M.G.J.

Review: The author's main points have to do with the inadequacies of reliability engineers and they are well taken. (A minor characteristic he neglected to mention is that they sometimes forget to proofread their papers carefully.) Many of the deficiencies the author points out could be overcome if production reviews were instituted along with design reviews. Drawings and specifications, by their nature, are incomplete so there needs to be face-to-face communication about how the item will actually be produced by the shop in addition to the kinds of things the designer has put on the drawing. One of the reasons that the reliability and quality departments are often in conflict with design and manufacturing departments is that the goals of the organization are not defined clearly enough by higher management and thus each interprets its actions as fulfilling the real desires of management. Perhaps the dichotomy between design and manufacturing in most companies is responsible for some of the difficulties the author mentions. These dichotomies and difficulties are very real; the practice in some companies of having a team follow through from design through production is often helpful in alleviating these problems, since then the design and its production are not considered two entirely separate things. These difficulties that the author is graphically portraying are characteristics more of people in general than of occupants of particular kinds of jobs. For example, most people who have put out fires in production situations have noted that there is a wide disparity between the way the design engineering department thinks the part is made, the way the shop foreman thinks the part is made, and the way the girl on the production line is actually doing it. The paper makes valid points, and its contents should be familiar to everyone in a manufacturing organization.

R70-15089 ASQC 817; 612; 882

A SYSTEMS UNAVAILABILITY TRADE-OFF PROGRAM

Van B. Parr (Collins Radio Co., Dallas, Tex.) *In: Proceedings of the 1970 Annual Symposium on Reliability, Los Angeles, Feb. 3-5, 1970* Symposium sponsored by the Institute of Electrical and Electronics Engineers, Institute of Environmental Sciences, American Society for Nondestructive Testing, and American Society for Quality Control New York IEEE, Inc. 1970 p 319-325 9 refs

Computer program SORCBE for generating a profile of system unavailability (steady state) versus added cost is described. Certain parameters of each unit in the system can be varied through a maximum of three steps, with the added cost for each step being specified. The parameters which may be varied are: (1) failure rate (assuming exponential failure density function for each unit), (2) mean-time-to-restore; (3) inspection and renewal period; (4) sparing period; (5) turn-around-time (time required to get another unit when spares are exhausted); (6) probability of having sufficient spares throughout the sparing period; (7) number of spares; and (8) unit unavailability. An approach is used which allows one pass through the system, thereby reducing the run time on the computer. Author

Review: This is a further development of computerized calculations of various reliability factors by this author. It is a general description of the program with an example. Thus, one can follow the description in principle but, obviously, is unaware of many of the details. The use of the term *undominated points* is understood only in the context of the reference given for it, and those not familiar with the term will not understand that portion of the paper. It would seem to be worthwhile to develop approximate methods for estimating the bounds on the error incurred with this method, but, as the author implies, it will be difficult to do so. There is no indication of the availability of the program from the author or his company; thus, the paper can be interpreted as publicity for this calculation method (which is worthwhile) rather than an offering of the method to the profession. Those who have not used such programs should be aware of the following considerations. (1) The time, effort, and money to get one of them on the air is appreciable. (2) Once the learning period is over, such a program provides extensive benefits for the engineering and reliability groups.

R70-15095 ASQC 814; 838; 871

SOME ECONOMIC ASPECTS OF MAINTENANCE VERSUS REDUNDANCY FOR MANNED SPACE STATIONS

Alain G. Mona (Mc Donnell-Douglas Astronautics Co., Western Div., Space Systems Center, Advanced Space and Launch Systems, Experiment Modules, Huntington Beach, Calif.) *In: Proceedings of the 1970 Annual Symposium on Reliability, Los Angeles, Feb. 3-5, 1970* Symposium sponsored by the Institute of Electrical and Electronics Engineers, Institute of Environmental Sciences, American Society for Nondestructive Testing, and American Society for Quality Control New York IEEE, Inc. 1970 p 404-409 6 refs

An investigation based on studies of earth orbital space stations housing four to six men for 1 year shows a distinct economic advantage of manned repair over redundancy for the purpose of increasing equipment availability. Analysis of results shows that, in order to nullify this advantage, either of two conditions is necessary: a drastic shift in the costing structure of space-stations programs or a strong increase in the time for performing maintenance tasks predicted by current studies. Only the second condition is considered a realistic possibility. Author

Review: The topic of this paper is important, and the analysis appears to have been done caregully. In searching for the why of the results, it is obvious that Table 4 contains the key data. A stated assumption is that the reliability improvement is the same whether

the extra hardware is installed initially or put on board as a spare. Presumably the type of redundancy involves automatic switching of an inactive unit whereas the manned repair involves the removal and replacement of the unit by hand. (It is possible in the first case that the actual switching would be done manually, but presumably there would be no disconnecting and connecting of hardware.) Therefore, apparently the only question to be considered is how difficult it is to have the transfer from an active to an inactive unit done with some kind of a manipulation of a "switch," and how much is involved in taking apart the hardware with wrenches, etc. and connecting a new unit. If this is not the situation, then the article is not clear; if it is the situation, it would help to discuss this basic idea further. Obviously, the problem attacked in this paper is an extremely important one, as are the conclusions.

R70-15103 ASQC 810;844; 851
General Dynamics/Electronics, Rochester, N.Y.
WHEN DOES QUALITY BECOME RELIABILITY ?
J. Douglas Ekings *In* Am. Soc. for Quality Control Reliability and Quality: Teamwork for Prod. Effectiveness 1969 p 45-66
(N69-36733; A69-25971) Avail: CFSTI

Reliability engineering applied to a complex electronics equipment, requires the use of technical and management methods, if the specified reliability is to be achieved. The reliability program must provide direction to all major functions of the business cycle. Secondarily, use of quantitative data is required to assess the results of these efforts. The assessments, to be effective, must be of a simple and direct form, readily comprehended by production personnel, middle management, and top management. Author

Review: A more appropriate title of this paper would be "A Specific Approach to Reliability Program Management." Toward this goal, the author does a good job of describing his company's reliability requirements in the design and manufacture of a specific system. The paper will be useful to reliability managers who wish to compare their methods with those of another organization. It can also provide a good perspective on reliability program management to inexperienced personnel. The author is certainly correct in recognizing that reliability must ". . . provide directions and controls, but it cannot do the work of the designer, the manufacturer, or the tester." The specific relationship between quality and reliability referred to in the title is not discussed directly until the concluding part of the paper. Some workers in reliability and quality will undoubtedly disagree with the author's viewpoint that reliability represents merely an expansion of the efforts traditionally assigned to quality. Instead of attempting to resolve this age-old argument about the distinction between reliability and quality, it is more important to recognize that certain responsibilities must be exercised to achieve over-all program success and it matters little in the end whether it was done under the guise of reliability or quality.

R70-15104 ASQC 813; 612; 871
Pan American World Airways, Inc., New York.
AN INTEGRATED COMPUTERIZED RELIABILITY MONITORING PROGRAM FOR AIRCRAFT SYSTEMS AND COMPONENTS
N. Ron, A. L. Reznick, and L. Das *In* Am. Soc. for Quality Control Reliability and Quality: Teamwork for Prod. Effectiveness 1969 p 67-77 ref
(N69-36734; A69-25972) Avail: CFSTI

Proposed is a computer program that will attempt to correct deficiency problems in aircraft systems and components as they arise by automatically supplying the processed data necessary for decision making and corrective action. The program attempts to optimize such parameters as cost, utility, and response within the reliability function of aircraft maintenance systems by means of statistical tools, flag out systems and components that show any undesirable trend in their performance. G.G.

Review: According to the introductory remarks, the computerized program described in this paper represents an attempt to process large volumes of reliability, cost, and maintenance data and provide key data to aid decision-making. Unfortunately, the description is poorly presented so that persons who are not already intimately familiar with the problem being treated can, at best, hope to obtain only vague ideas of what is being accomplished. Routine steps performed monthly with the program are listed without any rationale given for them, thus making technical assessment impossible. In a private communication, the first author has confirmed that there is a typographical error in the description of step 2 of the monthly routine. It should read: "Compare with UCL. If UCL is exceeded, generate type-1 alert." In the discussion of output, several printouts and graphs are presented as illustrations with little description. The reviewer considers it regrettable that the material in this paper is not better presented so that the potential contribution is readily available to more readers.

R70-15106 ASQC 810; 813
SOME INTERNATIONAL ASPECTS OF RELIABILITY AND QUALITY: SYNOPSIS
E. H. Hayes (Quality Assurance Northern Electric Co., Limited, Ottawa, Ontario, Canada) *In: Proceedings of the 1969 Reliability and Quality Control Seminar, Niagara Falls, Ontario, Canada, Apr. 12, 1969* Seminar sponsored jointly by the American Society for Quality Control (Buffalo section) and Society of Reliability Engineers [1969] p 109

The more interesting international activities in reliability and quality are reviewed. Two kinds of organizations are mentioned: those who are international in operation with formal representation from selected countries, and those who are national but whose influence is international by reason of tradition, or technical excellence. International symposiums sponsored by either category are mentioned. Author

Review: Unique problems can readily arise when technical programs, sale of products, and operation of systems cross international boundaries and involve persons from more than one country. Common bases for communication in terms of mutually understood definitions, standards, specifications, policies, and procedures can resolve many of these problems. This paper gives a brief description of several international reliability and quality organizations playing significant roles in this regard and also identifies certain national organizations which strongly influence international practices in reliability and quality. (A helpful list of addresses of these organizations is also given in appendices.) Some comments are also given on international aspects of certain reliability problems. It was interesting to learn, for example, that cultural-related phenomena were, in a case cited, an important factor of the environment. Also, the in-transit environment in other countries can be quite different from that typically encountered in this country. It appears that there is much to be gained from international sharing of reliability and quality information.

R70-15107 ASQC 813; 844; 851
General Electric Co., Syracuse, N.Y. Semiconductor Products Dept.
ECONOMICAL RELIABILITY PROGRAM DESIGN

B. L. Bair and A. Fox *In* Am. Soc. for Quality Control Reliability and Quality: Teamwork for Prod. Effectiveness 1969 p 111-126 refs Presented at Ann. Symp., Chicago, 1969 (N69-36736; A69-34496; R69-14476) Avail: CFSTI

Semiconductor reliability programs can be used to evaluate products, to determine design margins, to set specification limits, to evaluate process changes, and to determine the extent and types of programs for control of product families. This paper emphasizes the need for careful experimental design in order to meet program objectives in an economical manner. Program design elements such as parameter measurements, control of the measurements, types of stress tests, levels of stress, and some of the techniques of analyzing the data to be generated are described. The goals of reliability evaluations are discussed, and a comparison program is developed which could be utilized by a manufacturer to assess the effects of a proposed process change. Author

Review: This paper is the same as the one covered by R69-14476.

R70-15108 ASQC 813

Motorola, Inc., Chicago, Ill. Consumer Products Div.

THE RELIABILITY OF THE QUASAR COLOR TELEVISION RECEIVER

Richard A. Kraft *In* Am. Soc. for Quality Control Reliability and Quality: Teamwork for Prod. Effectiveness 1969 p 151-158 (N69-36738) Avail: CFSTI

Application of solid state devices in color television receivers resulted in improved reliability and reduction in service costs. A plug-in modular panel design with ten circuit panels made it possible for service technicians to replace major functional elements simply by plugging in a replacement unit at a reasonable charge and thus keep service cost down. The marketing program for a particular solid state color television received good consumer response and thus confirmed the projected appeal of solid state products. G.G.

Review: Papers such as this are often of value to aerospace reliability engineers because they can show how industry—when not under government restriction—has modified the reliability programs to make them more efficient. Even though not explicitly noted in the paper, the product design described is a good example of how technological developments supported originally for improvements in aerospace systems can benefit the general populace in improved design of consumer products. Solid-state design is a well-proven concept for achieving high reliability. Modular construction has been slower in developing but has also proved to be of tremendous benefit in aiding maintenance of complex equipments where skills of maintenance personnel are limited. Higher initial costs have been a major deterrent to use of such concepts in consumer products; however, the paper indicates that public acceptance can be obtained if there is appropriate education on overall benefits. The paper provides an interesting, strictly narrative, account of the manufacturer's experience in promoting a product employing the concepts discussed above. As a technical paper, its major shortcoming is the lack of quantitative information to support its claims. It would have been interesting, for example, to compare overall costs to the consumer per operating hour for the product with those for similar products of other manufacturers.

82 MATHEMATICAL THEORY OF RELIABILITY

R70-15078 ASQC 821; 844

FAULT TREES FOR RELIABILITY ANALYSIS

R. J. Schroder (Logic Simulation, Kent, Wash.) *In: Proceedings of the 1970 Annual Symposium on Reliability, Los Angeles, Feb. 3-5, 1970* Symposium sponsored by the Institute of Electrical and Electronics Engineers, Institute of Environmental Sciences, American Society for Nondestructive Testing, and American Society for Quality Control New York IEEE, Inc. 1970 p 198-205 12 refs

Aspects germane to the utility of fault trees in reliability analysis are discussed. Three purposes which fault trees serve in evaluating system failures are identified: (1) A fault tree aids in determining the possible causes of an accident, and often leads to discovery of failure combinations which otherwise would not have been recognized as causes of the event being analyzed. (2) The fault tree serves as a display of results. If the design is not adequate, it can be used to show how the weak points lead to the undesired event; if it is adequate, the fault tree can be used to show that all conceivable causes were considered. (3) For reliability analysis, the fault tree provides a convenient and efficient format for the problem description particularly when Monte Carlo simulation is used. An example of a fault tree representing unsafe failure of a fail-safe system is depicted, and the symbology is defined. Author

Review: This paper is a tutorial introduction to the use of fault trees. A fault tree analysis is logically equivalent to a probability of success analysis but is often more convenient to use. An insufficient distinction is made between statistical and physical independence in the early part of the paper, but it is not serious. Another limitation of fault trees (and of many other methods of analysis) is that they are generally restricted to situations where good/bad is a sufficient description of an element, and always restricted to the case where an element has only a finite number of states. If the elements have more than two states (good/bad), the analysis rapidly becomes more complex. This is a reasonably good introduction—it is no better and no worse than many. Therefore, if one has it available, it is worthwhile reading; if not, one need not go out of his way to find it if others are available.

R70-15079 ASQC 823

CORRELATION OF RELIABILITY PERFORMANCE MEASUREMENTS

J. E. Anderson (International Business Machines Corp., Owego, N.Y.) *In: Proceedings of the 1970 Annual Symposium on Reliability, Los Angeles, Feb. 3-5, 1970* Symposium sponsored by the Institute of Environmental Sciences, American Society for Nondestructive Testing, and American Society for Quality Control New York IEEE, Inc. 1970 p 206-211 3 refs

Experience data have been accumulated on different programs using the IBM 4 Pi computer line. In these programs, two significant characteristics were observed. First, a decreasing failure rate both in the short term AGREE environment and through several thousands of hours in field use was noted. Secondly, the correlation factor between the test and field MTBF is not constant, but indicates a function converging toward unity with machine age. The factors causing this observation in this predominately integrated circuit equipment are postulated. The data definitely indicate an improvement in MTBF with equipment age of the same vintage build. Both the point of measurement initiation and the interval of time when the measurement is performed will affect the results. The measurement environment is shown to affect the slope of the failure rate decrease. While there are definitely interrelationships between these factors, a single variate approach can be used to bound their effects. The expected reliability growth

with vintage of hardware is shown to be evident through development and early production. Author

Review: A thought that keeps recurring while reading this paper is the prevalent assertion in the elementary reliability literature: a properly debugged piece of equipment will have a constant hazard rate. This paper seems to reinforce the assertion that the previous statement is more of a definition of *properly debugged* than anything else. It is difficult to know whether to interpret the results in this paper as a reliability growth model of equipments with a constant hazard rate or as a truly decreasing hazard rate. Since the equipments are repaired, the terminology of a repair situation is more appropriate than that of single failures and no repair. So we could say that what is noted is a decreasing repair rate with operating time as well as with more recent time of manufacture. These data, in themselves, are valuable since there has been a great deal of speculation about these things but very few hard data. Reliability engineers (especially those who are theoretically inclined) as well as the theorists themselves should be aware of the data in this paper in order that they can take them into account in developing further the theoretical basis of reliability prediction. Of particular interest is the difference in failure rate noted under AGREE test conditions versus field use conditions.

R70-15080 ASQC 823

A UNIFYING RELIABILITY ANALYSIS PHILOSOPHY

K. A. Lyman (International Business Machines Corp., Owego, N.Y.) *In: Proceedings of the 1970 Annual Symposium on Reliability, Los Angeles, Feb. 3-5, 1970* Symposium sponsored by the Institute of Electrical and Electronics Engineers, Institute of Environmental Sciences, American Society for Nondestructive Testing, and American Society for Quality Control New York IEEE, Inc. 1970 p 221-227 2 refs

A large body of evidence is now accumulating which demonstrates that the total life characteristic of a system is an exhibition of a decreasing failure rate with time. All apparent behavior of the system can be shown to stem from a single time-to-failure distribution. The philosophy underlying this generalizing assumption and the physical and mathematical reasoning which supports it are discussed. Data from volume production programs in burn-in and subsequent field operation are used to demonstrate the validity of this approach. Author

Review: This paper is a rather extensive justification of the Weibull distribution for the life characteristic of electronic equipment. In particular, shape factors less than 1 (representing a decreasing hazard rate) are presumed to adequately describe these equipments. There are some minor difficulties with the presentation, particularly in the section entitled "Physical Reasoning." However, these difficulties do not affect the conclusions which are as follows. (1) The intersection of the probability density curves for stress and strength is not related to the probability of failure; rather, the probability of failure involves a convolution of the distributions. (2) The S-N diagram is not the same as a Goodman diagram. (3) Cumulative damage problems are not considered. There is some confusion in terminology about equipments which fail only once and are retired and those which fail and are repaired. This is obviously a repair situation, and what is being asserted is that the time between repairs is following a Weibull distribution. Regardless of the previous comments, this paper is a good exposition of the thesis of a decreasing hazard rate and the difficulties this causes when using tests wherein a constant rate is assumed.

R70-15090 ASQC 824; 433; 775; 851

RELIABILITY IMPROVEMENT THROUGH EFFECTIVE NONDESTRUCTIVE SCREENING

J. Isken and J. Saboe (TRW, Inc., Electronics Group, Philadelphia, Pa.) *In: Proceedings of the 1970 Annual Symposium on Reliability, Los Angeles, Feb. 3-5, 1970* Symposium sponsored by the Institute of Electrical and Electronics Engineers, Institute of Environmental Sciences, American Society for Nondestructive Testing, and American Society for Quality Control New York IEEE, Inc. 1970 p 326-330 2 refs

A method for evaluating the accuracy and efficiency of a nondestructive screen test is presented. Calculations for determining the sample size required to be within a + or − error limit of the true accuracy with a particular confidence level are shown. Bayes probability theorem is used to determine the efficiency of the screen test to correctly identify electrical components as potential failures. Author

Review: This is a statistical paper and shows the relationships (by means of Bayes' relation) between conditional probabilities. The algebra appears to be correct. Confidence limits for various sample sizes seem to be based on a Gaussian approximation which is, undoubtedly, satisfactory. The thing that is not shown is the confidence to be put in the result after having gone through Bayes' theorem. Since the result is the important probability, it would have been helpful to know the range of uncertainty for each calculated probability. The discussion associated with the formulas is good although some statistical background is necessary in order to follow it. The derivation uses very standard statistical methods; therefore, the contribution lies in their application to this particular kind of test rather than the development of new statistical methods.

R70-15092 ASQC 824

ESTIMATION OF HAZARD RATE FROM INCOMPLETE DATA

L. A. Morris (North American Rockwell Corp., Autonetics Div., Anaheim, Calif.) *In: Proceedings of the 1970 Annual Symposium on Reliability, Los Angeles, Feb. 3-5, 1970* Symposium sponsored by the Institute of Electrical and Electronics Engineers, Institute of Environmental Sciences, American Society for Nondestructive Testing, and American Society for Quality Control New York IEEE, Inc. 1970 p 337-342 2 refs

Possible solutions are investigated for the problem of estimating the reliability function at a time when a significant percentage of the members of the data sample has not experienced failure. A general method is presented for fitting the failure rate of a system as a function of age using the incomplete field data. The method enjoys relatively simple mathematics and a ready means for testing goodness of fit. Author

Review: This paper presents a method of passing a set of orthogonal polynomials through failure time data. The author explains the theory involving the weighting functions. The method of calculating the uncertainty is not explained fully but presumably involves using the calculated variance which is shown at the top of p. 340. In any interpolation method of curve fitting such as this, it must be emphasized again and again that extrapolations are completely meaningless since it is an interpolation formula that is being developed. This is somewhat different from the usual cautions expressed by statisticians where the parameters of physical formulas are estimated from the data and extrapolation just gets rather uncertain. In the case of the method in this paper, extrapolation is absolutely prohibited by the very nature of the situation and any observations of the behavior of the hazard rate curve outside the region of the data are completely irrelevant and most misleading. The formula is only for smoothed interpolation.

R70-15093 ASQC 824; 433
CLASSICAL CONFIDENCE INTERVALS HAVE A BAYESIAN INTERPRETATION
Ralph A. Evans (Research Triangle Institute, Research Triangle Park, N.C.) *In: Proceedings of the 1970 Annual Symposium on Reliability, Los Angeles, Feb. 3-5, 1970* Symposium sponsored by the Institute of Electrical and Electronics Engineers, Institute of Environmental Sciences, American Society for Nondestructive Testing, and American Society for Quality Control New York IEEE, Inc. 1970 p 343-347 1 ref

Classical one-sided confidence statements give a confidence limit and a confidence level. These same numbers can be generated in the Bayesian approach if the prior distribution is chosen properly. The prior distribution is shown to be proportional to the slope of the contours of constant probability when the statistic under consideration is plotted vs the parameter about which an inference is to be made. This prior distribution is often a constant, or is closely related to a prior distribution which is a constant. Since these distributions are often associated with complete ignorance, this notion is discussed. Alternatives to the use of classical confidence intervals are proposed. Author

Review: The point of the paper is well taken and one which should be of interest to engineers who do not possess extensive background in the application of Bayesian techniques to confidence interval determination. The author has taken pains to introduce his point in great detail, stating what he intends to show and explicitly defining his terms (with the exception of $\Psi = \ln\theta$, which he defines just before his concluding remarks). The development of the paper is brief, almost to the point of not being conclusive (e.g., not enough attention is given to the rigor associated with the partial differentiation). The examples are pertinent and well constructed; they relate directly to general reliability applications. The conclusions are stated clearly, although cautioning about transformation is over-emphasized and the comment about "ignorance" needs more development (especially since this was a major objective).

R70-15098 ASQC 824; 838
INCLUSION OF TIME CONSTRAINTS AND REDUNDANT ACCESS ON SPACECRAFT RETURN PROBABILITIES BY THE CONCEPT OF BOREL SET
S. T. Chu and A. R. Nagy, Jr. (Aerospace Corp., Vehicle Systems Div., El Segundo, Calif.) Reprinted from *Journal of Spacecraft and Rockets*, vol. 6, no. 6 June 1969 p 667-672 7 refs
(Contract F040701-68-C-0200)
(A69-39017)

Application of the linear Borel set concept to develop a logic for properly counting and summing a complex and juxtaposed set of coverage belts in estimating the return probability of a spacecraft. Two factors are evaluated as examples: (1) the impact of a daylight return requirement, and (2) the appraisal of safer emergency recovery plans when unacceptable weather or sea state conditions exist at the initial recovery site. Sample results show that the local time constraints have a significant effect on the return probability. The seasonal variation of available daylight hours can also have a pronounced influence on the return probability, and on the waiting time for an assured emergency return if the recovery sites are in the same hemisphere. It is shown, however, that redundant access of the second degree, while having a lower return probability than single access, does not greatly increase the required waiting time for an assured emergency return. I.A.A.

Review: The authors have been quite successful in finding an unusual application for a mathematical technique in order to calculate the reliability of recovery of spacecraft. The topic itself is an important one, and the authors have made a valuable contribution by finding a way to make this calculation very efficiently. Although a theoretical paper, it is used to calculate a very practical result, and this will be of value to trade-off studies in recovery planning.

R70-15099 ASQC 821; 844
COMPOSITE SYSTEM RELIABILITY EVALUATION
Roy Billinton (University of Saskatchewan, Power System Research Group, Saskatoon, Saskatchewan, Canada) (*IEEE Winter Power Meeting, New York, Jan. 28-Feb. 2, 1968, Paper* 6 p) *IEEE Transactions on Power Apparatus and Systems*, vol. pas-88, no. 4, April 1969 p 276-281 5 refs
(TN2306)

The application of a conditional probability approach to the determination of a reliability index at any point in a composite system is discussed. A general design criterion is postulated in terms of quality of service rather than continuity. Using a Markov approach, it is shown that the effect of storm associated failures on the system failure probabilities is dependent upon the degree of redundancy in the configuration under study. The effects of shunt compensation, on-load tap changing, and variations in allowable voltage levels on the reliability of a simple configuration are illustrated. Using the techniques described, it is possible to arrive at a measure of steady-state adequacy for any point in a system and, particularly, at those points at which major transmission terminates and subtransmission begins. Author

Review: The first part of this paper gives a brief review of some probability theorems. (The wording is not always quite correct, but probably generally understandable. For example, page 277, the bottom of column 2, the formulas are true even if the events are independent. At the top of the next column, the subevents B_j not only must be mutually exclusive, but they must form an exhaustive set.) The balance of the paper applies these formulas to a complete power system including both generating and transmission capacity. The criterion for failure is not simply the presence or absence of the voltage, but the presence of the voltage within the proper range. Several of the analyses are asserted to be the results of the Markov approach, the details of which are not given. The mathematics is quite straightforward although some background of probability theory is essential to an understanding of the paper. Power system engineers will generally find this kind of calculation helpful just as similar calculations are helpful for aerospace engineers. Power systems and aerospace systems have much in common, the foremost being complexity of analysis. Also, rarely can one analyze everything about the entire system but rather one must make his analyses about subsystems with more gross approximations as the entire system level is approached. It is of interest to both groups to see how the other is handling the analytic difficulties. This paper is a good example of how power system engineers are trying to bring reliability mathematics to the assistance of their system analyses.

R70-15100 ASQC 824; 431
FREQUENCY AND DURATION METHODS FOR POWER SYSTEM RELIABILITY CALCULATIONS. PART 2: DEMAND MODEL AND CAPACITY RESERVE MODEL
Robert J. Ringlee and Allen J. Wood (General Electric Co., Schenectady, N.Y.) (*IEEE Summer Power Meeting, Chicago, June 23-28, 1968, Paper* 14 p) *IEEE Transactions on Power Apparatus*

and Systems, vol. pas-88, no. 4, April 1969 p 375-388 10 refs

The work is aimed at incorporating a model of the power system load with the generation system model developed previously. Combination of this load and the generation model permits computation of the availability, frequency of occurrence, and mean duration of generation reserve, or margin states. The most widely applied of the previously developed techniques for assessing generation system reliability, the loss-of-load and loss-of-capacity methods, assume fixed outage or load duration intervals. The present model, on the other hand, uses an exponential distribution of durations. The reserve margin states developed using the exponential distributions contain data giving both the availability of each margin state and the expected frequency of recurrence. The method presented and illustrated may be extended to consider the calculation of operating reliability or the inclusion of the effects of a simple transmission system. Author

Review: It is interesting for aerospace engineers to read this kind of paper because they can learn several things: (1) Perhaps foremost among them is that the grass is not much, if any, greener on the utility side of the fence than on the aerospace side. The utility people find considerable difficulty in evaluating the future exactly as does anyone else. (2) There is a growing use of the more sophisticated probabilistic/statistical techniques in the utility industry as a means of making more accurate predictions more easily. (3) If the utility includes all of the variables and their statistical dependencies and lack of stationarity, the total computation problem will have the same order of complexity as an aerospace vehicle, and it will not be convenient to use such techniques as a simple Markov process. (4) There does not appear to have been much tendency to use historical data in the formulas and make predictions which can be checked by other historical data. This is about the only way to verify that the mathematical model being used is a reasonably accurate one. This paper is a good example of a practical extension of probabilistic/statistical techniques in the utility prediction area. The added discussions also provide valuable insights into the method and various reactions to it. As one of the discussants emphasized, a practical limitation on the usefulness of many mathematical techniques is th amount of good solid data available to put in them. As the techniques become more sophisticated and exact, many parameters are unknown or known only probabilistically. The aerospace industry has seen this happen. (This paper is a continuation of the work started in the paper covered by R69-14766.)

R70-15101 ASQC 824; 431
RELIABILITY ANALYSIS FOR POWER SYSTEM APPLICATIONS
K. Neil Stanton (Purdue University, West Lafayette, Ind.) (*IEEE Summer Power Meeting, Chicago, June 23-28, 1968 Paper 7 p*) *IEEE Transactions on Power Apparatus and Systems,* vol. pas-88, no. 4, April 1969 p 431-437 8 refs

The block diagram reduction technique for reliability analysis is reviewed and compared with the use of the state transition matrix. It is pointed out that an efficient technique now exists for calculating system mean time between failures directly from the transistion matrix, and this fact removes the major advantage possessed by the reduction technique. The superior flexibility of analysis using the transition matrix and the fewer approximations that are necessary seem to favor this approach for further power system applications. Author

Review: It is interesting to compare this paper with the paper by Ringlee and Wood on pp. 375-388 in the same issue of the IEEE Transactions on Power Apparatus and Systems (see review in this issue of RATR) in which many figures of merit were associated with reliability. In the present paper, only mean-time-to-failure and system availability appear calculable. The approach is straightforward and makes extensive use of computer calculation for Markov processes. The theory is obviously useful also in the aerospace field. The paper appears to be competent; it pushes one point of view, namely the use of Markov processes and associated matrices as a basis for a systematic approach which is well suited to digital computer utilization in the case of large systems. However, it does explain other methods of handling the problems. Those with some knowledge of matrix mathematics will find this paper a suitable tutorial introduction to calculating reliability although, for example, it does not calculate margins of power reserve capacity.

83 DESIGN

R70-15061 ASQC 831
EFFECTIVENESS MODEL OF AN ANTI-AIRCRAFT FIRE CONTROL SYSTEM
Hans I. Ebenfelt (Industri-Matematik *AB*, Lidingo, Sweden) and H. Robert Holmqvist (Sweden Armed Forces Board of Administration, Stockholm, Sweden) *In: Proceedings of the 1970 Annual Symposium on Reliability, Los Angeles, Feb. 3-5, 1970* Symposium sponsored by the Institute of Electrical and Electronics Engineers, Institure of Environmental Sciences, American Society for Nondestructive Testing, and American Society for Quality Control New York IEEE, Inc. 1970 p 68-74

A system concept especially suited for systems engineering purposes and cost effectiveness analysis is presented. This concept is used in the modelling of system effectiveness for a fire control system. The system capabilities are transformed into a function of system states and tactical environment states. Measures of system effectiveness are compiled under risk and uncertainty with respect to the tactical environment. Author

Review: This paper gives a straightforward approach to determining the effectiveness of a system. The determination is possible under a simplified set of conditions. Even though the authors suggest in several places that other considerations can "easily" be taken care of or that the problem could be solved with other assumptions just as "easily," the *easily* refers to the situation *in principle*, not in practice. In practice, it would be much more complicated. The method determines the effectiveness under a particular set of conditions. There is no analytic way of altering the allocation of resources to increase the effectiveness. Presumably, this is done by trial and error. Papers of this type appear in the literature from time to time, each author claiming that his approach is different. While this may be true, these approaches have a great deal in common. Regardless of the novelty of this approach, it is a good explanation; the editorial polish is poor in places, but generally the meaning is easily decipherable. In any such analysis, it is important to remember, as the authors do point out, that the model which will be used for the system is strictly an approximation to the real world. When comparing systems, if the values of effectiveness are reasonably close, the unstated assumptions may become important in choosing between the several possibilities.

R70-15062 ASQC 831

SYSTEMS EFFECTIVENESS EVALUATIONS

Sol Levine (Naval Material Command, Anti-Submarine Warfare Systems Project Office, Washington, D.C.) *In: Proceedings of the 1970 Annual Symposium on Reliability, Los Angeles, Feb. 3-5, 1970* Symposium sponsored by the Institute of Electrical and Electronics Engineers, Institute of Environmental Sciences, American Society for Nondestructive Testing, and American Society for Quality Control New York IEEE, Inc. 1970 p 75-83 8 refs

Details are presented on an antisubmarine warfare (ASW) systems effectiveness evaluation which is defined as an analytical study performed to assist a decision-maker in choosing from several alternative courses of action. This study examines the performance, including reliability, maintainability, and availability, of existing or proposed ASW subsystems when operating together as an entity under likely environmental and tactical conditions. From this examination, the relative worth of the alternatives is assessed. A mathematical model, used in a computer simulation, represents the dynamics of friendly aircraft, surface ships, and submarines; the performance characteristics of their ASW systems; the dynamics and tactics of the opposing forces; and the characteristics of the ocean environment. The computed results are evaluated, and a sensitivity analysis is made to determine which parameters have the most influence on effectiveness. The results of the computer simulation are used as a management tool to aid the decision-maker's judgment. M.G.J.

Review: A sensible procedure for conducting a systems effectiveness analysis is presented in this paper. Emphasis is on the effectiveness features, and cost considerations are mentioned less frequently. The paper consists entirely of discussion accompanied by several flow diagrams. Several equations are noted on two of the figures. Where redundancy is present, as well may be the case for Anti-Submarine Warfare (ASW) systems emphasized in this paper, these simpler equations are not applicable. The paper does not make clear whether this procedure is just a plan for ASW effectiveness analysis or whether it has been implemented meaningfully. The latter is not a trivial task, requiring a significant level of effort. It is easy to infer from the paper that these procedures were not implemented at the time the paper was written. In a private communication, the author has commented as follows. "Although the procedure was developed for and is being implemented in ASW programs, it is applicable to most complex hardware programs that use computer modeling and simulation of real-world situations to evaluate the worth of alternative solutions to system problems. Many systems effectiveness studies do not treat reliability and maintainability as variable parameters, but assume a fixed value of 1.0 (i.e., no failures)."

R70-15063 ASQC 833; 814

DESIGN OF RELIABLE YET ECONOMICAL INDUSTRIAL CONTROL SYSTEMS

C. A. Cianfrani and J. N. Stanley (Leeds and Northrup Co., North Wales, Pa.) *In: Proceedings of the 1970 Annual Symposium on Reliability, Los Angeles, Feb. 3-5, 1970* Symposium sponsored by the Institute of Electrical and Electronics Engineers, Institute of Environmental Sciences, American Society for Nondestructive Testing, and American Society for Quality Control New York IEEE, Inc. 1970 p 106-110 5 refs

The application of reliability technology to industrial control systems is discussed, with emphasis placed on design engineering and specification of components which contribute significantly to total system costs. The importance of considering overall system integrity at the system development phase is stressed. Operational parameters to be considered in hardware development are cited, and six areas requiring specific attention in achieving reliability during the design engineering phase are identified. Guidelines for selecting components and obtaining failure rate data are included. M.G.J.

Review: This paper contains good practical advice. Even though it is directed toward industrial control systems, much of it is applicable to the aerospace industry (not everyone in the aerospace industry is oblivious of cost). Many of the authors' admonitions are equivalent to "work smarter, not harder." They wisely suggest that components not be considered by themselves but as part of the circuit in which they will appear, the object being to get the least expensive circuit. Obviously, one should carry this as far as is economically feasible since the object is not really to get an economical circuit but to get an economical control system, etc. In making that kind of a decision, there is no substitute for experience. Insofar as feasible, the authors do give the many kinds of details to which one must pay attention in achieving high reliability. There are no detailed checklists, but this paper would be helpful in making one. Obviously, not all industrial suppliers agree with the negative decision on integrated circuits, but the details of any particular decision are not important as long as the many pertinent factors have been taken into account. On this point, the first author in a private communication has commented as follows. "In the paper, the point was that discrete components individually were inexpensive, but that other costs must be considered. When all is analyzed, integrated circuits would probably be cheaper (and therefore, should be used) due to savings in packaging, mounting and assembly. Moreover, the reliability of IC's is inherently higher than comparable discrete circuitry. We went on to justify the use of the zener transistor family of IC logic in many control systems." One factor the authors did not mention is that older established companies with an excellent reputation to protect are more prone to let someone else make all of the mistakes in trying the new things--the newer companies often push state-of-the-art techniques which may not be quite as reliable but offer something else. All in all, this is a good paper and can be read with profit by those who are in the equipment manufacturing business.

R70-15066 ASQC 830; 844

CIRCUIT DESIGN SELECTION: A RELIABILITY FACTOR

B. L. Retterer (ARINC Research Corp., Annapolis, Md.) *In: Proceedings of the 1970 Annual Symposium on Reliability, Los Angeles, Feb. 3-5, 1970* Symposium sponsored by the Institute of Electrical and Electronics Engineers, Institute of Environmental Sciences, American Society for Nondestructive Testing, and American Society for Quality Control New York IEEE, Inc. 1970 p 192-197

The study was directed toward the discovery of relationships between circuit design characteristics and reliability. The existence of such relationships might provide the designer with a procedure by which he could assess the different reliability levels offered by different circuit configurations that meet performance requirements. The only intent of the investigation was to evaluate the feasibility of the concept as applied to various electronic power supplies. While thus hampered by a narrow data base, the analysis did suggest several potential guidelines and indicate that the significance of reliability engineering during the design process can be increased. Author

Review: This paper presents the results of a study designed to show that reliability and design *do* have an inseparable interface and that reliability analyses can be used *within* the design

effort instead of simply being a parallel operation. The study is limited in scope, as the author points out, and the conclusions thus are rather weakly substantiated. The author's conclusions, however weak, are well taken. The paper has a specialized message for the circuit designer; it is not for the general reliability engineer.

R70-15071 ASQC 833
SOME PRACTICAL PARTS CRITERIA
P. H. Fowler and H. J. Bailey (TRW Systems Group, Redondo Beach, Calif.) *In: Proceedings of the 1970 Annual Symposium on Reliability, Los Angeles, Feb. 3-5, 1970* Symposium sponsored by the Institute of Electrical and Electronics Engineers, Institute of Environmental Sciences, American Society for Nondestructive Testing, and American Society for Quality Control New York IEEE, Inc. 1970 p 273-283 6 refs

The growth of new parts technologies and designs is discussed in terms of its impact on parts engineering methods. It is pointed out that the type of effort provided by the parts engineer must change accordingly, from parts specialties to design specialties, from vendor evaluations to packaging evaluations, from parts analysis to functional analysis, and from specialization to generalization. Consideration is given to program planning criteria, selection criteria, procurement criteria, application review, and reliability interface. M.G.J.

Review: This report appears to suggest that the "parts engineer" or components specialist is obsolete, having been superseded by the functional engineering specialist. But the authors do not prove their hypothesis; rather, they lend support to the conclusion that there is no significant difference between the so-called "obsolete" and the "new" parts specialist. They seem to be inventing another cult based on management's failure to force the components specialist to keep up with the newer technologies. The paper contains many questions but few answers. It seems that the intent was to present a case for the need of an intermediary between the components specialist and the system designer. The authors outline all the tasks the specialist should perform, the questions to be asked, the actions to be taken, and the records to be kept. It is reminiscent of the management consultant's rule which warns that for each weakness the staff finds in an operation there are many who will define a new task for themselves. Here is an excellent opportunity to locate alternatives and reduce the cost of having another level of specialist in the act. In summary, this paper is long and offers little really useful information.

R70-15072 ASQC 832
MAN AS A PART OF THE DESIGN ENVIRONMENT
J. W. Christopher (Chrysler Corp., Space Div., New Orleans, La.) *In: Proceedings of the 1970 Annual Symposium on Reliability, Los Angeles, Feb. 3-5, 1970* Symposium sponsored by the Institute of Electrical and Electronics Engineers, Institute of Environmental Sciences, American Society for Nondestructive Testing, and American Society for Quality Control New York IEEE, Inc. 1970 p 114-119

The concept is presented of including workmen as one of the environmental variables that must be considered in any design. The design is not complete unless the designer assumes responsibility for the survival of his product as it interfaces with workmen during fabrication, assembly test and use. A design which fails to survive predictable encounters with men is just as unsatisfactory as the design which fails under predicted vibration loads. The great majority of today's problems were begot yesterday by designers who did not consider workmen on the environments list. So, do not just enquire what part failed but also enquire what characteristic of workmen the designer failed to consider. Author

Review: The author is attacking the problem of the human as part of the environment by means of the failure reporting system. Very roughly, his thesis is that if you have not found the human reason for the failure, you have not found the real reason. There is much to be said for this point of view. One of the difficulties involved with getting report forms filled out without too much dissembling (or even outright lying) is that people are most reluctant to say they performed poorly or that one of their associates did, and since bosses are in the habit of seeing machinery blamed for the errors, each person hesitates to be the one to say that people are at fault even though it is true. This is a case where the system is such that when each person maximizes his own benefits, the system as a whole suffers. The author makes an excellent point, one which many people in the reliability business wish was obvious enough and ingrained enough that it need not have a special paper written about it. Unfortunately, such is not the case. Failure reporting forms are rarely the solution to any problem, but those in the failure reporting and analysis business should give this paper some serious consideration so that people will be recognized as a legitimate environment in which equipment must operate.

R70-15074 ASQC 831; 612; 821
RELIABILITY ANALYSIS OF REACTOR SYSTEMS
Friedrich W. Heuser (Interatom, Bensberg/Koeln, Germany) and Guenter G. Weber (Kernforschungszentrum Karlsruhe, Germany) *In: Proceedings of the 1970 Annual Symposium on Reliability, Los Angeles, Feb. 3-5, 1970* Symposium sponsored by the Institute of Electrical and Electronics Engineers, Institute of Environmental Sciences, American Society for Nondestructive Testing, and American Society for Quality Control New York IEEE, Inc. 1970 p 135-145 10 refs

Monte Carlo methods for evaluating system reliability are assessed. Approaches for analyzing system reliability are presented with special consideration of systems important for the German Fast Breeder Project. Fault trees are shown, and data requirements are discussed. A computer program related to the safety analysis by fault tree evaluation is applied to the emergency power source of the fast breeder reactor, and a structure function equivalent to the fault tree is discussed. A simulation of dependent components is proposed, and the fault tree of a two out of three system is evaluated. Author

Review: This paper takes the fault tree approach for analyzing the reliability of a system and modifies the conventional approach to be more realistic and easy to use. The authors justify their choice of methods by repeated reference to engineering considerations and have attempted to handle such perennially distressing difficulties as statistical independence and very low probabilities. Even though the paper is rather tersely written, it can be followed by someone who has had experience with Monte Carlo methods and with fault trees. It is not suitable as a beginner's tutorial paper, but can be read with profit by those who are interested in the analysis of large systems and wish to know how other people are handling the problem. The section on statistically dependent components is good; it obviously is not the only way to handle them but is probably at least as good as the data permit. The paper is recommended reading for theoretically-inclined reliability engineers.

R70-15077 ASQC 838; 844

ESTABLISHMENT OF A REDUNDANCY PRIORITY FOR SPACECRAFT ELEMENTS

Eugene R. Carrubba (Avco Corp., Systems Div., Wilmington, Mass.) *In: Proceedings of the 1970 Annual Symposium on Reliability, Los Angeles, Feb. 3-5, 1970* Symposium sponsored by the Institute of Electrical and Electronics Engineers, Institute of Environmental Sciences, American Society for Nondestructive Testing, and American Society for Quality Control New York IEEE, Inc. 1970 p 186-191 2 refs

The technique is intended primarily as a planning tool in the early stages of a space program. Required inputs are estimates of equipment reliability and spacecraft resources. Values are subjectively assigned for the relative importance of the various spacecraft constraints to the program and for the relative criticality of the various spacecraft elements to mission success. The reliability gain per spacecraft resource is determined for each of the elements and weighted by the constraint importance values. These results are then further modified by the mission criticality values to establish a redundancy priority ranking for the various spacecraft elements. Author

Review: This is a good paper. It presents a modest kind of analysis and does it without claiming that it will solve all the world's problems instantly. This is the kind of analysis which people ought to be making in any kind of reliability improvement regardless of whether spacecraft, or even redundancy, are being considered. As the author mentions, many of the criteria are highly subjective. This is not necessarily a disadvantage since, at this stage, virtually everything is highly subjective anyway. The important thing is to channel these subjective feelings in a manner that gives reasonably consistent results and seems to be rational. The author's consideration of the change in reliability, the using of resources, and the criticality of the elements are all important. One may choose a slightly different set of resources, for example, without losing the utility of the method. Even though these ideas are not necessarily new, this is a good discussion of the technique, and it can be read with profit by anyone who has to make decisions regarding the upgrading of reliability.

R70-15094 ASQC 832

PEOPLE SUBSYSTEM MEASUREMENT FOR TOTAL RELIABILITY

Ben P. Davis and Carl N. Cordoni (IBM Federal Systems Div., Cape Canaveral, Fla.) *In: Proceedings of the 1970 Annual Symposium on Reliability, Los Angeles, Feb. 3-5, 1970* Symposium sponsored by the Institute of Electrical and Electronics Engineers, Institute of Environmental Sciences, American Society for Nondestructive Testing, and American Society for Quality Control New York IEEE, Inc. 1970 p 394-403 6 refs

The need for quantifying and developing valid techniques for the prediction and analysis of the human component is discussed, and an empirical approach is described to the problem of people system reliability. The method is used by IBM at the Cape Kennedy Facility to control its people system supporting the Apollo/Saturn Program. Details are given on the collection, analysis, and feedback of failure data and failure rates. It is believed that the basic concepts described are applicable to personnel subsystems of all degrees of complexity and for any industrial application. Through a set of rigorous definitions of the intersected areas of the personnel subsystem parameter segments, a valid stochastic model of the personnel subsystem is considered feasible. A model of this nature can then be used to control the design, production, and test of a personnel subsystem. M.G.J.

Review: This is an excellent article prepared with precision and accuracy. It is a technical presentation which is inherently difficult reading not written so as to hold a reader's interest. This could be due to having two authors whose styles differ considerably. Measuring the reliability of a man-machine system is valuable and necessary. The approach described in this paper appears straightforward. The procedural system is described without detailed discussion on the validity of data collection practices, editing procedures, or the difficulty of collecting the data for each segment of the equations. It would seem that segmentizing the input data into as many constituent parts as has been done would be a drawback in further applications. All users do not have the luxury of having data processing equipment readily available. The authors do not define each component interrelationship of the Personnel Subsystem and so state (top p. 395). While this is understandable in view of the scope of the paper, it would have been useful to cite a reference where more detail may be found. For those involved with systems which are dependent upon man-machine relationships, this paper is worthwhile reading.

R70-15102 ASQC 831; 844

Bell Aerosystems Co., Wheatfield, N.Y. Rocket and Propulsion Systems Reliability Dept.

SERVICE LIFE PREDICTIONS

In Am. Soc. for Quality Control Reliability and Quality: Teamwork for Prod. Effectiveness 1969 p 35-43 refs

(N69-36732; A69-25970) Avail: CFSTI

A method for predicting the service life of a system is discussed. Procedures for identifying and testing system variables for both operational and non-operational phases of a mission are discussed. Statistical techniques for obtaining service life estimates from variables test data are outlined and the predicted service life of the system is observed to be the shortest of the service life estimates for the family of variables. Author

Review: In the strict sense the technique discussed in this paper leads to estimation of service life rather than prediction as stated in the title. The paper gives an easily-readable, narrative description of an approach for service life estimation based on tests of items deliberately removed from service. The discussion is devoted more to "what to do" than to "how to do"; however, anyone experienced in systems analysis and test planning will readily comprehend the implied tasks. The approach, itself, is not unique as it has been used for other defense systems. Also, it is considerably simplified in the case described since time is the only influencing variable. The approach does consider the treatment required if many variables had to be taken into account in the regression models. As described, the approach implies that a large population of operational items exists to provide an adequate sample without significantly depleting the population. A logical modification of the approach for few-of-a-kind systems, such as space system ground-support equipment, or for expensive items such as aircraft, is to collect variables data from nondestructive in-service status-monitoring tests and use them for estimation. The coverage of the variables with this modified approach cannot, of course, be as extensive as the approach described in the paper. It should be noted that the benefits of service-life estimation are limited primarily to repair and replacement scheduling if the design and production phases are completed.

R70-15105 ASQC 830; 612

Bell Aerosystems Co., Buffalo, N.Y.

COMPUTER-AIDED RELIABILITY TECHNIQUES IN ELECTRONIC DESIGN

R. A. Nowacki *In* Am. Soc. for Quality Control Reliability and Quality: Teamwork for Prod. Effectiveness 1969 p 79-105 (N69-36735; A69-25973) Avail: CFSTI

In the past three years there have been many evolutionary changes in some areas of reliability engineering and analysis. Some changes are due to the use of the digital computer as an instrument for implementing reliability theory. The use of modern electronic data processing (EDP) techniques has made the practice of the trial and error approach and various optimization techniques practicable and efficient. This paper will discuss the more frequently used and most successful computer-aided techniques at the disposal of the reliability engineer in the design and analysis of electronic equipment for various applications and environments. Author

Review: Computers have become an important tool to reliability engineering for handling large volumes of data in large design and development programs. This paper identifies typical reliability engineering tasks and describes how computers can assist in performing them. It does not give enough detail for the novice to understand what is involved in each task. It will thus benefit primarily those experienced reliability engineers who are just now introducing computers into their programs. It will also serve those who wish to compare their efforts with those of another organization. It is easy to infer from the paper that the efforts for reliability and the computer programs for implementing them are mainly the property of reliability engineers. This is certainly not always the case (nor is it presumably what the author meant to imply). For example, circuit designers in some organizations are solely responsible for performing the failure modes and effects analyses with the belief that they are most qualified to understand immediately the effects of failures and to correct for the critical ones. Circuit designers are also often responsible for doing statistical and worstcase analyses of their designs before releasing them and thus use computer-aided design techniques extensively. In these cases, reliability engineering typically acts in a monitoring or consulting capacity. In a private communication, the author has stated that his organization recognizes this and has instituted a program to train designers in the use of such computer programs.

84 METHODS OF RELIABILITY ANALYSIS

R70-15068 ASQC 844

METAL BRIDGING UNDER PLANAR OXIDE

J. F. Knudsen (Lockheed Missiles and Space Co., Microelectronics Center, Sunnyvale, Calif.) *In: Proceedings of the 1970 Annual Symposium on Reliability, Los Angeles, Feb. 3-5, 1970* Symposium sponsored by the Institute of Electrical and Electronics Engineers, Institute of Environmental Sciences, American Society for Nondestructive Testing, and American Society for Quality Control New York IEEE, Inc. 1970 p 237-242

A failure mode and the failure mechanism are described for dielectrically isolated integrated circuits which incurred irreversible damage during electrical testing. Sizeable metallic bridging paths were observed underneath the planar oxide between emitter, base and/or collector metallization contacts in the active regions of integrated diodes and transistors. Microscopic inspection of the integrated circuits after lid removal showed bridging paths which appeared white in plan view. Electrical probing tests, precise metallographic cross-sectioning techniques, and X-ray microprobe results revealed highly conductive aluminum-rich channels within the monolithic silicon. These metal bridging defects beneath the silicon-oxide interface are imputed to erroneous orientation of the devices during automatic testing operations. Misorientation by 180° about an axis perpendicular to the top face of the package could allow excessive voltages to be applied in a forward bias mode across those junctions which were shorted or defective. Deliberate erroneous testing procedures in identical devices produced similar effects. Author

Review: This paper describes a neat case history of a foolish failure reminiscent of those that have appeared in the literature before (see, for example, the paper by Joseph B. Brauer covered by R67-13437). The cases reported by Brauer involved those in which the lid was improperly oriented upon the flatpack by the manufacturer; the present case involves that of the integrated circuit flatpack being placed improperly into an automatic tester by the user. In both cases the result is the same, viz., damaging voltages are permitted to appear at various nodes in the circuit. The author has presented the case clearly, although the quality of the photomicrographs reproduced in the paper do not make it possible to follow all the details to which the text refers. However, there will be little doubt in the reader's mind as to the validity of the conclusions. The observations on metal bridging of these overstressed circuits might be worthy of further study in themselves. That such metallic bridging paths could be formed by overstresses of the type that these circuits were subjected to is not obvious a priori. Shorts due to high temperature alloying can be visualized quite easily in the bulk of the transistor, but not growing along the surface in the manner in which these bridges were formed. Conceivably, the findings of this case history could have implications beyond the obvious corrective action.

R70-15069 ASQC 844

SURFACE RELATED FAILURE MECHANISMS IN INTEGRATED CIRCUIT ARRAYS

D. J. Fitzgerald and A. S. Grove (Intel Corp., Mountain View, Calif.) *In: Proceedings of the 1970 Annual Symposium on Reliability, Los Angeles, Feb. 3-5, 1970* Symposium sponsored by the Institute of Electrical and Electronics Engineers, Institute of Environmental Sciences, American Society for Nondestructive Testing, and American Society for Quality Control New York IEEE, Inc. 1970 p 249-250

The principal properties of the insulator-silicon interface are reviewed, and the various charges and states associated with the oxide-silicon interface are summarized. The failure mechanisms in digital integrated circuit arrays, which result from changes in these properties, are described. Author

Review: This short paper is actually a two-page abstract of the subject. It describes succinctly the various charges found in the oxide or at the oxide/silicon interface common to virtually all silicon structures fabricated today. The purpose of the paper is to describe failure mechanisms originating at the surface or interface region and the paper concludes by ticking off four surface-related failure mechanisms that have been encountered in the past. Clearly, the authors have the outline of a very interesting and worthwhile paper; most readers interested in this topic will look forward to further work on it.

R70-15073 ASQC 844; 831

LONG TERM STORAGE AND SYSTEM RELIABILITY

Stanley M. Cherkasky (Singer-General Precision, Inc., Kearfott Div., Little Falls, N.J.) *In: Proceedings of the 1970 Annual Symposium on Reliability, Los Angeles, Feb. 3-5, 1970* Symposium sponsored by the Institute of Electrical and Electronics Engineers, Institute of Environmental Sciences, American Society for Nondestructive Testing, and American Society for Quality Control New York IEEE, Inc. 1970 p 120-127 7 refs

A comprehensive study of storage and its relation to system reliability are presented. Nearly all systems are subject to performance degradation while in a dormant state. Failures found in the nonoperating mode are of the same basic type as those found in the operational mode, though precipitated at a slower rate. Concepts of system dormancy, supporting data, and recommendations for diminishing present indecision are provided, with emphasis on the significance of the following related topics: the nonoperating or sedentary failure rate; math modeling; and checkout philosophies. Special consideration has been given to the importance of system tradeoff studies, encompassing availability, reliability, and cost. Author

Review: This is a topic in which there is much interest and little information. This paper provides a service in bringing together what is in the literature but it adds no new information. Thus, those who have been keeping up with the government reports on this topic will find little of value in it. Others can use it as a good starting place. None of the applications seem to be storage environment versus the space environment. There are many who now believe that the space environment can be one of the most benign known. If there are any designers and reliability engineers who still did not know that failures occur during storage, this paper is must reading for them. The author does make the presumption that the hazard rate is constant during storage. This is not universally accepted. The degradation may go on continuously, but often the failure occurs when the equipment is energized. The assumption of constant hazard rate is made here for essentially the same reasons as it is made elsewhere, namely, that there are rarely sufficient data to justify a more complex hypothesis.

R70-15076 ASQC 844

RELIABILITY PHYSICS - AN ASSESSMENT

Joseph Vaccaro (Rome Air Development Center, Griffiss Air Force Base, N.Y.) *In: Proceedings of the 1970 Annual Symposium on Reliability, Los Angeles, Feb. 3-5, 1970* Symposium sponsored by the Institute of Electrical and Electronics Engineers, Institute of Environmental Sciences, American Society for Nondestructive Testing, and American Society for Quality Control New York IEEE, Inc. 1970 p 348-363 75 refs

Progress and future directions in studies of the physical and chemical mechanisms of degradation in semiconductor devices are discussed. The role of reliability physics, or physics of failure, is seen as representing a concerted attempt to supplement the probabilistic expressions for device reliability with a sounder physical basis derived from theoretical and experimental studies of the degradation process. The methods used in kinetic studies are described, with emphasis placed on the failure mechanism approach, failure mechanisms and failure distributions, device degradation, failure analysis, and reliability and screening. M.G.J.

Review: This is a generally good review of the area known in electronics as reliability physics (and the material is generally limited to electronics). An excellent statement in the introduction is ". . . More often in practice, however, only qualitative or conceptual models are achieved. . . ." Reviewers in these pages have, from time to time, pointed out difficulties in some of the references in this paper; for example, Kooi's work (see R68-13906) contains some mathematical errors, and reviewers have pointed out the extremely limited engineering applicability of Stewart's derivations (see R67-13215 and R68-13909). Nevertheless, they are a part of the reliability physics effort, and the author has combined a great many references to give substantially more than spot checks of the field. His qualitative observations about the status of reliability physics show a good awareness of the limitations and advantages of both the theory and engineering practice. It is easy for mathematical errors to creep into work of this sort, and the present paper is no exception. Equations 4, 5, and 6, while correct, are irrelevant since what was done is to take an equation, differentiate it, integrate the derivative, and come out with something different from the original equation. Therefore, Equation 6 should be exactly the same as equation 3 (when the P_F, t_F condition has been introduced); it would be the same except for P in equation 6 which obviously must be 0. Equation 3 was presumably the basic experimental observation; further analysis (e.g., Equation 8) should agree with it, not with Equation 6 which contains an unevaluated arbitrary integration constant. In many derivations which have been published purporting to show how something is derived, the final formula is an obvious result of having included a particular special condition in the derivation for which there is no justification except that it gave the desired answer. It is that kind of derivation which has tended to give some of the mathematics of reliability physics a bad name. Also, there has been a tendency to make a few casual assumptions at the beginning such as the Arrhenius equation and then forget their essential nature when discussing the results. This is a good summary, using a minimum of technical jargon, so that managers and those who are not experts in the field can use it to come generally up to date.

R70-15081 ASQC 844; 833

ULTRASONIC ALUMINUM WIRE BONDING FOR MICRO-ELECTRONIC APPLICATIONS

W. P. Cox, E. E. Anderson (Lockheed Missiles and Space Co., Sunnyvale, Calif.), and J. H. Anderson, Jr. (University of Rochester, Rochester, N.Y.) *In: Proceedings of the 1970 Annual Symposium on Reliability, Los Angeles, Feb. 3-5, 1970* Symposium sponsored by the Institute of Electrical and Electronic Engineers, Institute of Environmental Sciences, American Society for Nondestructive Testing, and American Society for Quality Control New York IEEE, Inc. 1970 p 228-236 3 refs

Aluminum wire containing one percent silicon is normally used in ultrasonic wire bonding. Wire samples from several manufacturers were studied and significant differences in properties were observed. The tensile strength of bonds made with the various wires was determined as a function of key bonding machines parameters. The effects of high temperature aging upon wire properties and bond strengths were studied. Author

Review: While the authors have done a fairly detailed and careful study of the "properties of silicon-doped aluminum wires used in making ultrasonic bonds to aluminum films on top of oxidized silicon" and have succeeded in showing a dependence of bond strength upon technique of bonding, no strong conclusions emerge from the work. Although they can show that aluminum wire containing 1% silicon can vary in structure from one manufacturer to another—all the way from that containing relatively large inclusions of silicon to that containing no visible silicon precipitates even after high temperature annealing—and do recommend that the more uniform mixture is to be preferred, the basis

for this recommendation proves to be nothing more than an intuitive feeling; no data generated by the authors support this conclusion—only references to other isolated incidents lend psychological support to it. Although the authors show that certain combinations of power and time during the bond formation are better than others and that the optimum conditions for any given wire vary from one manufacturer to another, they are unable to predict from basic properties or measurements what combination of independent bonding variables (power and time) will be superior. They leave the impression that the optimum combination must be determined empirically for each wire by each manufacturer each time. Consequently, the reader seeking a sure-fire recipe for high-quality ultrasonic bonding is likely to feel dissatisfied with this paper. Nevertheless, it is a detailed examination of the ultrasonic bonding process and will be welcome reading to others caught up in the throes of high-reliability ultrasonic bonding. That there is no easy answer yet will come as no surprise to these readers and it is they who will find this paper most worthwhile.

R70-15082 ASQC 844

ELECTROMIGRATION IN INTEGRATED CIRCUITS

I. A. Blech (The Technion, Dept. of Materials Engineering, Haifa, Israel) and E. S. Meieran (Fairchild Semiconductor Corp., Research and Development Lab., Palo Alto, Calif.) *In: Proceedings of the 1970 Annual Symposium on Reliability, Los Angeles, Feb. 3-5, 1970* Symposium sponsored by the Institute of Electrical and Electronics Engineers, Institute of Environmental Sciences, American Society for Nondestructive Testing, and American Society for Quality Control New York IEEE, Inc. 1970 p 243-248 25 refs

The theory of electromigration in bulk current-carrying conductors predicts insignificant material transfer for normal operating conditions of integrated circuits. However, experimental studies of electromigration in thin films such as used for interconnections in integrated circuits actually show large atom drifts, which may result in catastrophic failure of the circuit. The failure mechanisms of IC's due to electromigration are described. The precautions that must be exercised in the application of the presently-available reliability data to device performance are emphasized. Author

Review: This paper appears to have the following two objectives: (1) to review electromigration as a phenomenon and discuss its importance in integrated circuits, and (2) to critically examine some of the more recent work in the field such as that by James R. Black in Proceedings of the IEEE, vol. 57, Sep 69, pp. 1587-1594 (see review in RATR, May 1970). No new data are given in this paper. (For a description of recent work by these authors, the reader should see J. Appl. Phys., vol. 40, Feb 69, pp. 485 et. seq.). The review portion of the present paper emphasizes the role of gradients (in temperature, structure, or composition) upon the mass transport phenomenon and also the influence of various structural parameters. The critique portion of the paper warns that extrapolation of MTF from the test results of Black or others (based on test structures) can lead to large errors for actual integrated circuits. Use such results with extreme caution is the message of this part of the paper. In addition, the model presented by Black assumes mean-time-to-failure to be inversely proportional to the square of current density. This dependence is unique to Black and the authors attribute his ability to confirm it experimentally to his neglect of other gradients such as those in temperature. In general, the authors feel that present models are not adequate to allow meaningful prediction of the performance of metallization strips in any practical silicon structure, although they do allow that one can make qualitative engineering judgments about suitable steps to take in reducing susceptibility to electromigration-related failures.

R70-15083 ASQC 844

RELIABILITY PHYSICS INVESTIGATION OF INTEGRATED CIRCUIT FAILURES

P. H. Eisenberg and C. W. Scott (North American Rockwell Corp., Autonetics Div., Anaheim, Calif.) *In: Proceedings of the 1970 Annual Symposium on Reliability, Los Angeles, Feb. 3-5, 1970* Symposium sponsored by the Institute of Electrical and Electronics Engineers, Institute of Environmental Sciences, American Society for Nondestructive Testing, and American Society for Quality Control New York IEEE, Inc. 1970 p 251-259 21 refs Sponsored by Rome Air Development Center

In-depth study of equipment field and burn-in failures identified the major device failure modes, localizing certain failures to particular part types and vendors. Analytical techniques included dynamic radiography, package gas ambient analysis, electron beam and scanning, electron microscopy, and novel electrical parameter characterization procedures. Although corrective action and improved process controls had reduced failure rates, it was demonstrated that significant improvements in reliability could only be achieved through more sophisticated screens developed from a better mechanistic understanding of integrated circuit failure modes. Author

Review: This is a good paper. It is recommended reading for those who are concerned with the reliability of integrated circuits, whether from the production, use, or inspection aspects. The descriptions of how to find the failures are good, as well as the discussion of the physical basis for their causes. The paper gives a reasonably balanced picture to the neophyte in that it shows that correction of these causes of failure is difficult, even when they are known, and that determining the cause of failure is not always easy or clear-cut. Most of the pictures are reproduced resonably well.

R70-15084 ASQC 844; 813

THE EFFECTIVENESS OF PART PREFAILURE ANALYSIS

Robert C. Aakhus and Howard W. Luedtke (Honeywell, Inc., Ordnance Div., Hopkins, Minn.) *In: Proceedings of the 1970 Annual Symposium on Reliability, Los Angeles, Feb. 3-5, 1970* Symposium sponsored by the Institute of Electrical and Electronics Engineers, Institute of Environmental Sciences, American Society for Nondestructive Testing, and American Society for Quality Control New York IEEE, Inc. 1970 p 267-272

Prefailure analysis is defined as information obtained from failure analysis and used prior to release of parts to production. It provides continuing preuse controls on component reliability factors in all phases of product development. The analysis is performed by the reliability engineering section on input from specialists in evaluation, applications and specification groups; design, production, quality, and Failure Analysis Lab. The extent of latent defects and the risks involved are assessed at a point where the problem can be economically corrected. Efficient procedures are followed to insure component reliability. Various elements contributing to cost effectiveness are described. Cost effectiveness of prefailure analysis is dependent upon project committment, technical analysis, and vendors' cooperation. Reduction in failure rates, scrap, and less rework at assembly level are benefits derived from applying prefailure analysis. The results and recommendations are documented. R.H.C.

Review: This is another paper publicizing the pre-failure analysis activities of Honeywell. The thesis of the program is that one can produce greater savings by running an analysis of parts before they are used rather than after they are used and fail. In fact, the program has progressed to the point where the supplier has been asked to ship a pre-production batch of parts in order that they may be analyzed for potential failure modes and production defects. The authors show substantial cost savings due to the program, and even though gross cost savings are often difficult to define, this kind of program should be given consideration by everyone involved in the production of electronic equipment. Some may well come to the conclusion that in their particular operations, it will not be cost-effective, but it is nevertheless worth considering. This paper is a good description of the program, and many reliability engineers will benefit from reading it.

R70-15085 ASQC 844; 612

COMPUTERIZED RELIABILITY ANALYSIS USING REACT

Frederick Tatar (Philco-Ford Corp., Space and Re-Entry Systems Div., Palo Alto, Calif.) *In: Proceedings of the 1970 Annual Symposium on Reliability, Los Angeles, Feb. 3-5, 1970* Symposium sponsored by the Institute of Electrical and Electronics Engineers, Institute of Environmental Sciences, American Society for Non-destructive Testing, and American Society for Quality Control New York IEEE, Inc. 1970 p 284-291

A system of interrelated computer programs and a comprehensive parts data bank called REACT to support analysis activity in nearly every aspect of reliability assurance have been developed. This system has been organized to meet engineering needs at two levels: Total Program Level, where the entire complex of programs is used to support reliability assurance analyses at every stage of product development and use; and at the Independent Analysis Level, where programs are used individually or in groups to support problem or task-oriented activities. React provides the most effective use of every reliability dollar spent. This is accomplished by: standardized analysis methods, computerized data processing, extensive parts data bank, and output/input program coupling. Author

Review: This is a general description of the program and is sufficient to get someone interested but not to give him any details. The author seems to discuss realistically the problems of implementing such a program and thus give the reader confidence that the program can be useful. Such programs require extensive documentation, not only in terms of the program logic but also in all of the assumptions that have been made in the mathematics and engineering. There is some danger in the use of these programs (just as there has always been with engineering formulas) that they may be used blindly by engineers without regard as to what they really do or really mean. One should not expect to obtain the package of programs and then be able to go ahead and use it without the expenditure of appreciable time, effort, and money in getting set up. Each new person who uses it has to be indoctrinated. The author promises appreciable savings, especially in the preparation of reports, and these should not be overlooked. As the author points out, some engineers are reluctant to use such a program because they must learn another langauage. Ordinarily the time spent in learning such a language is most worthwhile; an engineer should be encouraged to do so. Apparently, only parts of the program are readily available from the author or his company. So in that sense, this is more a publicity document than a contribution to the literature. In a private communication, the author has stated that only the best programs that have had the most debugging (because of wide use) could be offered—the others are not mature enough.

R70-15096 ASQC 844

HYDRAULIC FILTRATION AND COMPONENT LIFE CORRELATION

E. C. Fitch, Jr. (Oklahoma State University, Stillwater, Okla.) *National Farm, Construction and Industrial Machinery Meeting of the Society of Automotive Engineers, Milwaukee, Sep. 8-11, 1969, Paper* 9 p refs

A new method of correlating hydraulic component contaminant tolerance levels with hydraulic filtration performance has been developed using a cleanliness level chart. The chart provides a means of expressing contamination levels from particle count data. Methods are discussed for deriving component tolerance levels and rating filter elements on the basis of their efficiency characteristics. The correlation achieved enables the designer to establish the performance, reliability, endurance, and ultimate life of the hydraulic equipment. Author

Review: The details of designing equipment to have a long life are an important part of the reliability discipline, and since most aerospace vehicles contain hydraulic systems, this paper is of importance to aerospace reliability. The general message of the paper is a good one, and the method of rating contaminated oils and filtration systems appears to be useful. There are some confusing points about the paper although they deal more with the theoretical development than with the practical application: (1) The physical units (of length) are not expressed as they often are in physics and this causes the following two difficulties of interpretation. (2) The unit of length turns out to be something of a location parameter. Its value affects the fit of the distribution to the data. (3) There is a minimum value of particle diameter for which this distribution can hold, namely, one unit of length (i.e., the density function must be zero for diameters smaller than the unit of length, e.g., 1 mm). (4) On page 3, column 1, is stated "A vertical distribution curve would have a zero average particle size, . . .". Due to point #3, a vertical distribution curve implies that all particles are equal to the minimum, namely, the unit of length being used. (5) Figure 2 tends to imply that the curve stops at N = 1. Since N stands for a density of particles, there is no reason why the curve should stop there, and nothing is lost by extending it down to zero. (6) On page 2, column 2, it states that ". . . the Gaussian distribution function having a logarithmic variate has provided a suitable model . . . This model, proposed by F. W. Cole . . . , uses a log-log^2 graph for plotting cumulative particle counts." The lognormal distribution and the log-log^2 distribution are not the same thing, and it is not clear that the author is distinguishing between the two.

R70-15097 ASQC 844

THE -S/N- FATIGUE LIFE GAGE: RESPONSE TO RANDOM INPUTS

Darrell R. Harting (Boeing Co., Instrumentation Space Development Lab., Seattle, Wash.) *The 1968 ISA Annual Conference and Exhibit, New York, Oct. 28-31, 1968, Paper* 13 p refs Previously announced as A69-31270 and in the *5th Proceedings of the Annual Test Measurement Symposium*

(A69-31270)

Some background material concerning the constant-amplitude characteristics of the -S/N- Fatigue Life Gage is given for reference. The response of the gage to a constant-frequency, completely random amplitude input strain is described. The interpretation of random response data is discussed, with emphasis on the use of strain multipliers to determine the constant-amplitude strain equivalent of a random experience. Author (I.A.A.)

Review: The fatigue life gage holds a great deal of promise for estimating and improving the reliability of mechanical structures. *It is this high promise that prompts people to misuse the* gage (hoping that it will do more than it actually will). This paper shows how the gage is to be used (especially when the inputs have random amplitude) and gives some clear descriptions of how it should not be used. Those with a firm background in fatigue testing will find the instructions reasonably good and followable. Those who are new to the field will undoubtedly find them almost too complex to follow properly. As the author has pointed out well, this is not a gage which any amateur can slap on and hope to get good results. Those who have not yet tried this gage would do well to experiment with it and find out in what ways it can improve their testing program as well as to explore its possibilities in actual service. The -S/N- Fatigue Life Gage Applications Manual was covered by R68-14132. A second edition of this manual is now available. It is published by Micro-Measurements, Inc., Romulus, Michigan, who have been licensed by The Boeing Company to produce the fatigue life gage commercially.

85 DEMONSTRATION/MEASUREMENT

R70-15065 ASQC 851
TESTING AND ASSESSMENT
Harold C. Jones (Westinghouse Electric Corp., Defense and Space Center, Baltimore, Md.) *In: Proceedings of the 1970 Annual Symposium on Reliability, Los Angeles, Feb. 3-5, 1970* Symposium sponsored by the Institute of Electrical and Electronics Engineers, Institute of Environmental Sciences, American Society for Nondestructive Testing, and American Society for Quality Control New York IEEE, Inc. 1970 p 162-172 6 refs

A tutorial approach is taken to the basic precepts of an integrated test program. The proper timing for the various levels of testing is related to the major program milestones. Various test designs are discussed, as are some of the practical aspects which influence test decisions. Author

Review: As a tutorial presentation, this paper does a reasonably good job of describing in narrative fashion the major concepts of testing in a major equipment program from planning through evaluation of production items. Even though the broad-brush treatment precluded much depth, it is obvious from some of the practical comments that the author speaks from experience and is familiar with the hard realities of testing. His recognition of the frequent misuse of accelerated testing is well taken. However, this reviewer feels that the author appears to place too much faith in the use of IDEP, FARADA, and PRINCE data on parts reliability in lieu of in-house testing. Information from these data banks do give some indication of the successes which others have had with the testing of particular parts; however, parts with the same designation but produced at different times have been known to differ considerably. The points made regarding the use of prior knowledge in test design and the use of test data (p. 167 in the paper) are good. The accompanying illustration, however, is too sketchy to be understood without seeing the cited reference or knowing the assumptions required to obtain the result. Also, the measure of *engineer's confidence* associated with the result needs more explanation. The paper contains a good bibliography on parts testing, accelerated testing, Bayesian testing, and test methods. More detailed discussion of test methods and concepts can be found in the report covered by R69-14629, which also contains many good references.

R70-15067 ASQC 851
RELIABILITY TESTING, UNIFORMITY EFFICIENCY, AND ECONOMY NEEDED
Lyman Sessen (Washington Navy Yard, U.S. Naval Weapons Quality Assurance Office, Washington, D.C.) *In: Proceedings of the 1970 Annual Symposium on Reliability, Los Angeles, Feb. 3-5, 1970* Symposium sponsored by the Institute of Electrical and Electronics Engineers, Institute of Environmental Sciences, American Society for Nondestructive Testing, and American Society for Quality Control New York IEEE, Inc. 1970 p 212-220 8 refs

Guidelines for reliability testing, introduced by the Advisory Group on Reliability of Electronic Equipment (AGREE), are reviewed. Emphasis is focused on the environmental test levels E, F, G, H, and J, MIL-STD-781, which cover increasingly wider temperature extremes. It was concluded: (1) Management should be acquainted with the advantages of using the most severe AGREE environment practical in reliability testing. (2) Management should be assured that the resulting lower MTBF does not indicate lowered reliability but usually higher reliability. Failing this, reliability should be reported as mean temperature cycles between failure. (3) All reliability testing should be conducted at standard, test level E, F, G, H, or J of MIL-STD-781. Resulting MTBF figures should be accompanied by the temperature cycle length. (4) Part failure rate data from standard AGREE testing should be correlated along the lines of MIL-HDBK 217A so that accurate AGREE predictions can be made. (5) Field operation data should be correlated to establish factors between various field environments and AGREE test levels. M.G.J.

Review: A very strong argument is made in this paper for concentrating primarily on the more severe environmental conditions in AGREE-type reliability testing. An equally strong argument is also made for replacing environmental profile simulation with the cycling-type conditions specified for AGREE-type tests. The rationale for these appears to be the premise that the test efficiency is increased due to more problem areas being uncovered as a result of the more severe stresses. The discussion is *basically good and the points are well-taken. The reader is re*minded, however, that the concept cannot apply to all situations; for example, when the increased severity of the environmental stress induces quite different failure or damage mechanisms than those which would occur at lower levels of severity or in the operational profile. Especially welcome in the discussion is the recognition that the approach can result in higher reliability even though higher failure rates during testing may be indicated. In this regard, the author is obviously asking for a significant change in viewpoint and attitude about reliability demonstration since accept-reject criteria would need revision. The secondary theme in the paper, i.e., that of correlating part failure rates with AGREE-type conditions also has some interesting aspects; however, the concept will face strong resistance from workers in the field. It does appear that it would overcome much of the present misapplication of quoted failure rates for which relevant operating conditions are unknown. It is not clear, however, just how the author would propose reporting part failure rates, since the ambient conditions of some parts can be quite different from those of the equipment in which they are used.

R70-15070 ASQC 851; 815
SUBCONTRACTING FOR PARTS SCREENING

R. J. Green and H. J. Bailey (TRW Systems Group, Redondo Beach, Calif.) *In: Proceedings of the 1970 Annual Symposium on Reliability, Los Angeles, Feb. 3-5, 1970* Symposium sponsored by the Institute of Electrical and Electronics Engineers, Institute of Environmental Sciences, American Society for Nondestructive Testing, and American Society for Quality Control New York IEEE, Inc. 1970 p 260-266

The subcontracting/negotiating concepts and experience are extended to direct and indirect forms of negotiations related to the screening task. The indirect approaches include the SRR approach, reliability improvement programs, and screening as required by the part specification. The direct approaches include simple screening inhouse, simple screening at a test facility, and use of a complex screening program. The subsequently useful result of these approaches is that the screening task becomes properly integrated with the other engineering design and production tasks. The set of screens thereby negotiated is not necessarily the same optimum that would be defined for screening per se, but is rather a practical package which the vendor or contractor can economically provide for the level of reliability needed. Author

Review: Any effort conscientiously spent on planning tests is generally well spent. The paper illustrates this well for parts screening. The idea of subcontracting parts screening is not new. Many companies rely on it simply because of the lack of adequate inhouse facilities. The idea of purposely subcontracting parts screening as a way of more efficiently achieving high reliability has not been promoted much. Subcontracting for that purpose requires intimate knowledge of the capabilities of the subcontractor (assumed to be primarily the vendor in this case) and letting him perform certain parts of the screening when it is obviously more efficient for him to do so. The dollar savings quoted in the paper on past programs appear to be an adequate attestation of its success. Flexibility in planning and carrying out the program is obviously a key to the success of such an approach. Because of the many practical aspects of screening which are discussed, the paper will be worthwhile reading for anyone concerned with the planning of screening tests. One concept not adequately covered was the checking of the subcontractor to insure that he was satisfactorily performing his intended functions.

86 FIELD/CONSUMER ACTIVITY

No abstracts in this issue.

87 MAINTAINABILITY

R70-15086 ASQC 871

AN APPROACH TO FIELD REPAIR OF AVIONICS COMPUTERS

Raymond A. Grueninger (International Business Machines Corp., Owego, N.Y.) *In: Proceedings of the 1970 Annual Symposium on Reliability, Los Angeles, Feb. 3-5, 1970* Symposium sponsored by the Institute of Electrical and Electronics Engineers, Institute of Environmental Sciences, American Society for Nondestructive Testing, and American Society for Quality Control New York IEEE, Inc. 1970 p 292-299

Avionics computer programs frequently include, as a contractual requirement, the development of techniques for repair of system subassemblies. The repair technique was developed to permit the removal and replacement of flat packs and discrete components on multilayer interconnection boards in the field. Generally, maintainability and field repair specifications require simplified techniques. The repair procedure described is intended for use in the intermediate level repair of avionics computers aboard carrier-based tactical aircraft, and has been used in land based depots as well. All component mounting arrangements surface and through-hole mountings as well as multiple location arrangements are included in the technique. Author

Review: This paper will be of value only to those persons concerned with field repair procedures for electronic assemblies. It presents a case history report of one company's approach to simplifying repair procedures and minimizing repair time for a particular equipment. There is little, if any, discussion of the important topic of how the repair process might affect the reliability of the rest of the system. The approach appears to be straightforward. The presentation is much more detailed than necessary.

R70-15087 ASQC 871

ON CONDITION MAINTENANCE PROGRAMS

Kurt Ahlborg and Stephen Crabbe (Pan American World Airways, Inc., John F. Kennedy International Airport, New York, N.Y.) *In: Proceedings of the 1970 Annual Symposium on Reliability, Los Angeles, Feb. 3-5, 1970* Symposium sponsored by the Institute of Electrical and Electronics Engineers, Institute of Environmental Sciences, American Society for Nondestructive Testing, and American Society for Quality Control New York IEEE, Inc. 1970 p 300-307 1 ref

The purpose is to describe the background and show the results of an On Condition maintenance program for aircraft components. The program depends primarily on statistical and engineering analyses and performance monitoring rather than on scheduled overhauls to determine operating limits. The program is used to monitor and control the performance of 155 Boeing B707 and B727 airplanes. Over 90% of the formerly time limit controlled components have been On Condition for more than a year. Results show that such a system of monitored On Condition maintenance can replace the more conventional fixed time between overhaul policy for most components. This has been done without adversely affecting performance. At the same time there has been a substantial reduction in maintenance costs. Author

Review: Several reports such as this by various airlines have appeared in the literature in the past several years. They indicate a growing sophistication in maintenance philosophy as well as an application of this sophistication to practicality. It is a case where the theorists and statisticians have put their efforts to effective use in reducing costs and, in many cases, improving performance. This paper is a good illustration of the philosophy which essentially amounts to deciding for each subsystem when is the best time to fix it, with the criterion for *best* being primarily a combination of safety and cost. There is apparently a great deal of cooperation in the airline industry in exchanging information on failure modes and effects, lifetimes, etc. so that all airlines can benefit from the knowledge of others. This kind of procedure can undoubtedly be looked at profitably by airlines and others who are

seeking to apply space-age technology and management to their own procedures. Even though this paper does not give the details nor the references to where such details may be found, the explanation of the philosophy is good; it is understandable and uses a minimum of jargon.

R70-15088 ASQC 875
MAINTAINABILITY DEMONSTRATION TEST PERFORMED ON A COMPUTER SYSTEM
Daniel W. Lowry (Control Data Corp., Space and Defense Systems Div., Minneapolis, Minn.) *In: Proceedings of the 1970 Annual Symposium on Reliability, Los Angeles, Feb. 3-5, 1970* Symposium sponsored by the Institute of Electrical and Electronics Engineers, Institute of Environmental Sciences, American Society for Nondestructive Testing, and American Society for Quality Control New York IEEE, Inc. 1970 p 308-318 5 refs

Both the theoretical and practical aspects of performing a maintainability demonstration test on computer systems to Test Method 2 of MIL-STD-471 are described, with emphasis on the practical aspect. In particular, the following topics are discussed: (1) a description of the equipment tested; (2) the method of selecting and preparing the corrective maintenance tasks for the demonstration test; (3) the test method, which consisted of obtaining an indication of a failure, performing the corrective maintenance tasks, and recording the data; (4) the repair crew qualifications and training; (5) an analysis of the test data both to determine compliance to Test Method 2 of MIL-STD-471, and to justify the statistical distribution of the test data; and (6) the relevance of the demonstration test results to the actual field operation of a computer system, revealing some of the serious limitations of performing a maintainability demonstration test on a computer system to Test Method 2 of MIL-STD-471. Author

Review: This is a case history report of one organization's effort in maintainability demonstration for a particular system. It will thus interest primarily those persons concerned with planning maintainability demonstrations (as opposed to mere calculation). The description is generally clear; one exception concerns why 150 simulated malfunctions were prepared when only 50 were used in the demonstration. The discussion on relevance of demonstration results to repairs on operational systems is very timely. The possible reasons given for existing inconsistencies can serve as guidelines to others on the data needed for resolving the differences.

88 AVAILABILITY

R70-15091 ASQC 882; 431; 824
REPAIR QUEUEING MODELS FOR SYSTEM AVAILABILITY
K. Grace, Jr. (Bell Telephone Lab., Inc., Whippany, N.J.) *In: Proceedings of the 1970 Annual Symposium on Reliability, Los Angeles, Feb. 3-5, 1970* Symposium sponsored by the Institute of Electrical and Electronics Engineers, Institute of Environmental Sciences, American Society for Nondestructive Testing, and American Society for Quality Control New York IEEE, Inc. 1970 p 331-336 4 refs

Several models for evaluating the steady-state availability of complex, continuously-operating systems are extended to the case of a limited number of repairmen servicing all types of units. The failure and repair processes are described by a closed-cycle, finite-source queueing model. An approximate model is introduced in order to reduce the amount of computation required. The system availability of a simple example is evaluated by the exact and approximate methods. Author

Review: This is a theoretical paper; the mathematics was not completely checked, but it appears to be quite competent. It extends the earlier work of the author (see R69-14472) in the trading-off of spares vs. repair facilities, while trying to maintain a high availability. As is usual, an exact solution is not feasible, and the author introduces approximations which are acceptable in the usual region of calculation. Those who wish to study the paper carefully will need the author's earlier paper. It is difficult to compare the author's result with those of others because even apparently minor differences in assumptions create an entirely different problem to be solved. In a private communication, the author has given the following corrections to the limits on the summations in equations (14). (1) In the second sum in each case, the lower limit is $X_m = N_m$, the upper limit is n_m. (2) The limits on the first sum should be (lower) $x_1 = N_1$ and (upper) n_1 for the first equation, and (lower) $x_2 = N_2$ and (upper) n_2 for the second equation.

SUBJECT INDEX

Typical Subject Index Listing

PROBABILITY
Procedures for applying sequential probability ratio tests in analyzing checkout and support equipment
TR-3 c84 R70-12733

SUBJECT TERM | REPORT NUMBER | NOTATION OF CONTENT | CATEGORY NUMBER | *RATR* ACCESSION NUMBER

The Notation of Content, rather than the title, is used to provide a more exact description of the subject matter. The category number and *RATR* accession number are used to locate the abstract-review appearing in the abstract section of *RATR*.

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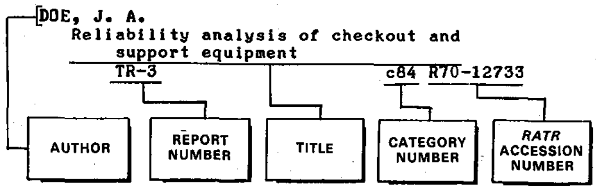
PERSONAL AUTHOR INDEX

Typical Personal Author Index Listing



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REPORT AND CODE INDEX

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ACCESSION NUMBER INDEX

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS VOLUME 10 NUMBER 6

List of *RATR* Accession Numbers

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NASA-Langley, 1970

Reliability Abstracts and Technical Reviews

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R70-15109—R70-15168

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The second section of *RATR* contains four indexes: The Subject Index is to assist in scanning or searching the literature on specific topics. The Personal Author Index identifies the publications of specific authors. The Report and Code Index is a listing of the report numbers of items abstracted and reviewed in the journal; this index also includes a listing of the ASQC codes for identifying the *RATR* accession numbers of the items to which the codes have been assigned. The Accession Number Index identifies the categories in which the abstract-reviews appear in the journal. Cumulative indexes are published annually.

EXAMPLES OF CITATIONS IN *RATR*

		ASQC CODES
RATR ACCESSION NUMBER	R70-12733 ASQC 844; 413	CORPORATE SOURCE
	General Equipment Company, Banville, Calif.	
TITLE	**RELIABILITY ANALYSIS OF CHECKOUT AND SUPPORT EQUIPMENT**	PUBLICATION DATE
AUTHOR	John A. Doe 23 Sep. 1969 27 p refs	
CONTRACT OR GRANT	(Contract NAS15-13411)	*TAB* AND *STAR* ACCESSION NUMBERS
REPORT NUMBER	(AD-629305; N69-15098; TR-3) Avail: CFSTI	SALES AGENCY AND PRICE

RATR ACCESSION NUMBER	R70-12739 ASQC 814	ASQC CODE
TITLE	**SEMICONDUCTOR RELIABILITY**	
	Joseph A. Smith (Eastern University, Arlington, Penn.)	AUTHOR AND AFFILIATION
JOURNAL REFERENCE	*Electric Journal,* vol. 8, Apr. 1969, p 478–492.	
	(A69-12569)	*IAA* ACCESSION NUMBER

RATR ACCESSION NUMBER	R70-12765 ASQC 773; 221; 823	ASQC CODES
TITLE	**TESTS OF SYSTEMS WITH SOME DEPENDENT FAILURES**	
	Joseph A. Smith (Eastern University, Arlington, Penn.) and B. James White (General Equipment Company, Banville, Calif.)	AUTHORS AND AFFILIATIONS
CONFERENCE OR SYMPOSIUM REFERENCE	*Association of Reliability Engineering, Failure Rate Conference, Olney, Tex., Mar. 13–17, 1969, 8 p.* Available from Assoc. of Reliability Eng., New York: $1.00	AVAILABILITY AND PRICE
IAA ACCESSION NUMBER	(A69-12407)	

VOLUME 10 NUMBER 7

Reliability Abstracts and Technical Reviews

A Monthly Publication of the National Aeronautics and Space Administration

July 1970

80 RELIABILITY

R70-15109 ASQC 802

INTEGRATED PRODUCT TESTING AND EVALUATION: A SYSTEMS APPROACH TO IMPROVE RELIABILITY AND QUALITY

Harold L. Gilmore (Syracuse University, Syracuse, N.Y.) and *Herbert C. Schwartz (Avco Corp., Systems Div., Wilmington, Mass.)*
New York John Wiley and Sons Sep. 5, 1969 365 p 38 refs

The value of product testing and evaluation functions and the need for applying management oriented techniques in decision making, and program formulation are discussed. Organizational planning, test and statistical methods, data reporting systems, and environmental controls are some of the important topics. Examples are used to illustrate industrial, aerospace, and commercial applications to conventional problems. It is recommended as a guide for engineers in the areas of system testing, design, reliability, quality control, production, and technical management.
R.H.C.

Review: This is generally a good book and can be helpful to those who have thrust upon them the responsibility for product test and evaluation. Any book which tells people how to do things will be controversial, and this one is no exception. Many of the sections which give detailed methods on how one ought to proceed are best viewed in the following way: If you have no idea on what to do, follow the book letter by letter; once you gain enough knowledge to argue with the book, then you will have to begin using your own judgment instead of the book. In most cases, the authors have tried to be flexible and explain the various ways in which things can be done, but sometimes the exposition seems rather arbitrary. Space and science buffs can note that the Introduction was written by Wernher von Braun and the Foreword by Isaac Asimov. The index is quite extensive. Chapter 1 gives some good illustrations of product testing. It is mostly for those who are relatively new to the field and need it better defined for them. Chapters 2 and 3 on the place of the testing organization in the company seem to have more arbitrariness in them, but, if the chapters are read intelligently and as a source of potential guidance (rather than as gospel), they can benefit those who are trying to determine where and how their group should fit into the company. The discussions on evaluating the economic impact of a capital decision may be strange to those who are new to management or accounting, but they are helpful (again, when read critically). Chapter 4, dealing with getting test facilities *on the air*, is handled largely by several detailed examples and will be helpful. Chapter 5 deals with the data, and needs a modest amount of picking and choosing on the part of the reader. For example, statistical decision theory is not the only good way of arriving at decisions. The text also emphasizes the uncertainty in the data, but there are many circumstances in which this uncertainty is negligible. With regard to data collection, it has been said by others that one should never take data unless he plans to analyze them, that he should never analyze them unless he plans to act upon the answer. The comments on corrective action are good, although many corrective actions are quite simple and not at all earthshaking. Chapter 6 on the integrated test program itself is rather straightforward. The tests being discussed are those which require complicated handling. These are not necessarily the kinds of tests the electronic technician performs at his bench in the course of developing a particular circuit. Chapters 7, 8, and 9 deal with particular environmental tests, and they can be very helpful as mentioned in the introduction above. (On page 153, it suggests that an ion gage ought to be accurate to $\pm 10\%$. It is a good ion gage system indeed which measures total pressure to that accuracy especially at low pressures when it is not even certain what gases are present. On page 179, the damage potential of a pulse is discussed. Ordinarily, if one knew the damage potential of a pulse, he would not even need to be performing the experiments. Damage potential is a characteristic not so much of the pulse as the object being pulsed.) Chapter 10 on statistical techniques is the chapter which can be most easily compared with a standard and, consequently, can suffer the most from such a comparison. Statements such as the following are difficult to interpret at best; at worst, they are misleading or wrong. (1) Page 240, "The area under the normal frequency distribution is used to measure probabilities." (2) Page 241, "This distribution is unique in nature. It is the curve of regression for the distribution of all small sample averages." (3) Page 242, "In an experiment, the experimenter wants to be unbiased." (4) Page 247, "It means equating two or more factors or treatments ..." (5) Page 247, "This is the nonadditive or unpredictable portion of the experiment." (6) Page 253, "This fact is utilized by equating new treatments to the higher order interactions." On page 242, it states, "However, it is assumed that the true mean is never known exactly unless an infinite number of observations is made." Whereas on the very next page, the statement says, "If there are thousands of observations in each of the samples, the sample means and standard deviations are equal to the population parameters, and prediction becomes unnecessary." These two statements contradict each other directly. There are better places to learn about statistics than this chapter. (There is a misprint at the bottom of page 247: the last two sentences should be different but are virtually the same.) Chapter 11, which is essentially on screening, is reasonable. Chapter 12 on government sources of data dwells at great length on STAR and mentions some of the

other sources. Only very modest attention is given to DDC. Chapter 13 is essentially a summary chapter. Appendix A gives some charts and block diagrams for ways of achieving traceability of measurements. Appendix B is a glossary; many of the descriptions are good. Those dealing with statistics are the weakest part; examples of poor definitions are for the *normal* distribution (it *can* be represented by only a single curve), and standard deviation--part a is presumably a definition, but in fact it is not.

R70-15120 ASQC 802

FATIGUE DESIGN HANDBOOK: A GUIDE FOR PRODUCT DESIGN AND DEVELOPMENT ENGINEERS

James A. Graham (Deere and Co., Moline, Ill.) Research sponsored by the Society of Automotive Engineers New York Society of Automotive Engineers, Inc. 1968 142 p 159 refs
(A69-10918; AE-4)

This book is a manual of procedures for the engineer and the designer to apply information on fatigue properties of materials and components in making decisions on design details. The general procedures of product development are considered from the point of view of the product's fatigue life, and types of the fatigue problems and fatigue properties of metals under various stress conditions as applied in laboratory fatigue tests are described. Special attention is given to determining load and stress on various machine parts and evaluating adequacy of design (determining the safety factor and the probability of failure - as well as using the cumulative damage theories for evaluation of new designs). Finally, the principles of designing for fatigue life are discussed. Additional topics considered are designing for low and high cyclic stress applications, predicting the fatigue life from service stresses or loads, applying the spectrum loading fatigue test, and increasing the life of machine parts by changing the stresses or modifying the fatigue behavior. IAA

Review: This handbook is a good engineering guide for applying information on the fatigue properties of materials and components to design. It was prepared from data submitted by leading authorities in the field; but, wherever possible, the editor and the contributors have avoided discussing the relative merits of the many theories on fatigue. Since the book is not a primer, it is essential that the reader have prior knowledge of fatigue behavior. There are several references to various design situations within the book. Specifically, there are chapters devoted to: product development procedures, different types of fatigue problems, fatigue properties, load and stress determinations, evaluation of design, and designing for fatigue life. Most of the fatigue data in the manual are for normal atmospheric temperatures, except for some limited fatigue data for aluminum, and the effects of corrosion on fatigue are not included. Since fatigue is such a universal failure mechanism, it must be considered by designers of all products—especially those in aerospace. This particular publication would be a valuable reference in the library of product, design, development, and materials engineers.

81 MANAGEMENT OF RELIABILITY FUNCTION

R70-15129 ASQC 810

ZERO DEFECTS: A MANAGEMENT STANDARD

Dwayne Gray (North American Rockwell Corp., Space Div., Downey, Calif.) *Quality Progress,* vol. 3, no. 3 Mar. 1970 p 30-32 2 refs
(ASQC 3/70-217)

Zero defects environment is defined as one in which managers perform the basic managerial functions in such a way as to encourage employees to work at the highest levels of their abilities. Human performance research demonstrated that the challenge of high performance standards, properly communicated, and meaningful recognition for meeting high standards are two big motivators in the industrial environment. It is noted that quality motivation programs have proved their worth. It is recommended that industry, government, and professional societies pioneer in understanding and refining the approach toward application of motivation methods, and insure that they are adequate, as well as meaningful, in a constantly changing environment. R.H.C.

Review: The Zero Defects program has had a controversial history, and many articles have been written about it ranging from quite negative to highly enthusiastic. The first part of this paper gives a balanced appraisal of the program so that a good perspective on it can be obtained. The rest of the paper goes on to show that the management functions in the plant must be reasonably well defined in order for a Zero Defects program to succeed. The discussion uses a moderate amount of jargon, and some familiarity with business-management terms is essential for understanding the paper. Ordinarily, those who are in the kind of management positions to benefit from the paper will have that background. The paper is well written and should fill the needs of many people who are concerned about where a quality motivation program can fit into their own plant. They can read the paper without feeling they are being led down the primrose path by someone with an axe to grind.

R70-15144 ASQC 814; 844

THE ECONOMICS OF THE RELIABILITY OF SUPPLY: COMPARISON OF STANDARDS ADOPTED IN VARIOUS COUNTRIES. PART 1: CONTRIBUTIONS [SELECTED PAPERS]

A. G. Milne (The Institution of Electrical Engineers, Power Div., London, England) *In: IEE Conference Publication, No. 34, London, England, Oct. 9-13, 1967* 87 p 237 refs

Reliability standards adopted in various countries regarding supply systems for generating electrical power are examined. Performance and cost are guides to engineering in achieving optimum design of system components. The effects of unit reliability on power systems are reflected in cost of the supply to its consumers; quality and availability; optimum use of national capital and resources; and flexibility in meeting demands throughout the system. R.H.C.

Review: This is a conference report and contains about 25 papers. Of these, about eight deal directly with facets of the reliability discipline as it is known in the aerospace industry. There are no sophisticated applications of complex theory but rather the papers are a direct effort to deal with the most important problems of cost of failure occurrence and failure prevention. The available data are explainable by relatively simple hypotheses, and there seems to be no desire to overly complicate things. The eight pertinent papers are discussed in more detail below.

1. "Economics of reliability of supply generation as derived by examination of continously running diesel plant in the tropics" by F. K. Fowkes

This paper treats the reliability of diesel engines used for stand-by electrical power. It stresses proper maintenance and proper operating conditions. Redundancy consisting of several smaller units is shown to produce higher reliability than a few large ones since the efficiency of a diesel unit is not tremendously affected by its size. It is a good summary.

2. "Estimation of reliability of supply in a power system" by J. Bergougnoux and P. Lelievre

This paper discusses the statistical characteristics of reliability and makes the usual simple assumptions such as exponential distribution and independent events. Generally, the long-run fraction of uptime (availability) is what is meant when the word reliability is used. The paper is rather statistical/mathematical in nature and discusses such things as state space. Some statistical sophistication is necessary for comprehension.

3. "Reliability of supply systems for power station auxiliaries" by H. Heimer and L. S. Chin

This is a good summary on using historical data of performance and life to evaluate the reliability of auxiliaries used in a power station. It is often not recognized by non-power engineers that the auxiliaries themselves consume tremendous amounts of power. They are vital to the operation of the station, and if the station is shut down they must be able to start up independently. The need is emphasized for good field data. This need is something that the electrical power industry shares with everyone else.

4. "Factors influencing the reliability and costs of transmission projects in the developing countries" by G. G. R. Argent, M. W. Kennedy and A. B. Wood

This paper presents a brief failure modes and effects discussion for transmission lines and mentions how redundancy in the transmission line can improve the reliability and availability. The balance of the paper discusses very briefly the reliability factors of other parts of an electrical power system and brings in the cost of improving reliability. It is a worthwhile discussion.

5. "Standards of reliability of supply in the developing countries and probabilities of failure" by G. G. R. Argent, M. W. Kennedy and A. B. Wood

This is largely a mathematical probabilistic approach to calculating failures in terms of the components of the system and the redundancy (structure). It is competent.

6. "The effects of unit reliability on power systems" by R. H. Hayward, J. G. Steel and D. T. Swift-Hook

This discusses failure rate versus cost trade-offs and shows how one strikes a balance between the cost of the failure and the cost of improving reliability. The need for such balance is universally felt. Only the simplest techniques are mentioned.

7. "The economics of reliability of supply-distribution (Great Britain)" by H. J. Sheppard

The main contribution of this paper is giving some fault rates for equipment. There is also a general description of important factors in keeping a power system up.

8. "Distribution system reliability performance" by M. W. Gangel and R. J. Ringlee

Again, there is a discussion of the cost of failure versus the cost of more redundancy in order to reduce the risk of failure. It is a worthwhile discussion.

These brief discussions serve a very useful purpose for power system engineers. Aerospace engineers will be interested in seeing the state-of-the-art in electrical power systems as far as the reliability discipline is concerned and can profit from the perspective thus obtained. The aircraft industry itself is operating virtually as a utility and there also, while safety is of paramount importance, the long-run availability is more important than the probability of failure.

R70-15146 ASQC 813

F-111A RELIABILITY

R. J. Allen, M. C. Fondon and C. A. Hardy (General Dynamics-Fort Worth Div., Research and Engineering Dept., Fort Worth, Tex.) *In: Proceedings of the 1970 Annual Symposium on Reliability, Los Angeles, Feb. 3-5, 1970* Symposium sponsored by the Institute of Electrical and Electronics Engineers, Institute of Environmental Sciences, American Society for Nondestructive Testing, and American Society for Quality Control New York IEEE, Inc. 1970 p 128-134

The F-111A Air Force contract required the design of an aircraft capable of performing its intended function with a high degree of dependability and effectiveness. The reliability on the aircraft level for the F-111A, the Air Force tactical fighter, is presented. The items discussed are: a general description of the F-111A, the reliability program implemented to assure attainment of required reliability, reliability characteristics of the F-111A design, development of inherently high reliable hardware and the inclusion of redundancy and alternate mode capability for critical aircraft functions, and F-111A mission reliability requirement imposed by contract and achievement based on flight data. Author

Review: It is difficult to assess the value of a paper such as this, but at a minimum it is worthwhile having the results in the literature and the paper can provide good background information for those who read it. The program described does represent one which was working at the state-of-the-art with regard to the hardware itself, the reliability requirements, the evaluation of the reliability, and the specifications for achieving all this. Even though the difficulties in achieving the reliability are not described in detail (due, at least in part, to the required shortness of the paper), the reliability growth is shown from a 40% mission failure to a 10% mission failure. To the newcomer in the field of reliability, the paper reads so smoothly that he may not get a feel for the extreme difficulties that were undoubtedly encountered during the development and production of this aircraft. (Also, he should be aware that in a paper published publicly such as this, neither party to the contract wishes to emphasize anything that is detrimental. For example, there is no mention of the difficulties that the press has reported–perhaps wrongly–in operation of the aircraft. In these respects, the paper is, of course, no different from those which fill the published literature.) Many readers will find the paper of good value for reference purposes as well as for its portrayal of a strenuous reliability effort.

R70-15152 ASQC 810; 612

A SOFTWARE RELIABILITY PROGRAM

Oscar L. Williamson, Gordon G. Dorris, August J. Ryberg, and Wayne E. Straight (Federal Electric Corp., Huntsville, Ala.) *In: Proceedings of the 1970 Annual Symposium on Reliability, Los Angeles, Feb. 3-5, 1970* Symposium sponsored by the Institute

of Electrical and Electronics Engineers, Institute of Environmental Sciences, American Society for Nondestructive Testing, and American Society for Quality Control New York IEEE, Inc. 1970 p 420-428 7 refs

A framework for the development of a software reliability program suitable for application at the initiation of the planning phase is presented. The development phases, reliability, functional analysis, and error source and effect analyses are discussed in a software context. A software reliability theory and a reliability analysis for a sample software system are presented. Concepts which have proven useful in evaluating a hardware reliability program are utilized. Author

Review: The authors have attempted to present a procedure for ensuring that all of the things that should be done in a software program are, in fact, done. The individual items–checking tolerances, round-off errors, etc.–are not new in themselves. What the authors appear to be after is the systematic consideration of each one of the effects and an estimate of the errors caused in the output by each one. Even though they concluded that ". . . there is no existing software reliability program of a general nature," there is probably no existing reliability program of a general nature for hardware, either, in that sense–except the conventional attention-to-detail. The authors do not suggest a design review; they did not go into the management aspects of the program in order to assure that the things which ought to be done are, in fact, done. They do list some important considerations in software development; they are presuming that the things which have been done for years to improve reliability will also be done; for example, breaking down the program into subroutines. One of their main efforts has been to develop some reliability mathematics for software which is directly analogous to that for hardware using the exponential distribution (constant hazard rate). There is no guarantee that the actual behavior will follow the hypothesized equations, but they provide a worthwhile focus for the discussion. In general, programmers or those who manage programmers can benefit from the ideas in this paper. The extent to which they are carried out, of course, must also take its place in the cost-effective line.

R70-15156 ASQC 813; 844
National Aeronautics and Space Administration. Goddard Space Flight Center, Greenbelt, Md.
MSFN RELIABILITY FOR A LUNAR LANDING MISSION
May 1969 43 p
(N69-28368; NASA-TM-X-63563; X-834-69-204) Avail: CFSTI

The reliability analyses are based primarily on failures experienced during flight support status. Previous analyses and predictions of MSFN reliability for supporting the lunar orbiting mission, Apollo 8, were reported prior to the mission. This report presents similar predictions about the MSFN reliability for supporting the forthcoming lunar landing, which is scheduled for July, 1969. The reliability predictions differ from the previous ones in that these predictions incorporate data from a larger number of missions; and consider the fact that two manned vehicles must be supported simultaneously during the phases when the LEM decends, lands and stays on the lunar surface, ascends, and docks with the CSM. These phases put the MSFN to a more severe use; however, the predictions herein indicate that the MSFN will be able to successfully support the mission. Author

Review: This report appears to be addressed principally to systems management for the purpose of conveying the status of predicted reliability and availability for the system and a specific mission. It accomplishes this purpose quite well in that it provides comprehensive coverage and presents the results in brief summary form readily useable by systems management. This assumes that management is already aware of the procedures and assumptions used in the analysis or has complete confidence in the ability of the analysis group since very few of the details about the prediction models and the system are included (they are presumably covered extensively in other documents). In Section 3, the term *dual sites* is confusing until one realizes that a dual site is one capable of simultaneous communication with two spacecraft within a single antenna beamwidth. Hence the reliability at a dual site is much less than for two independent sites. Because of the lack of detail, the use of the report by others will be limited to a general illustration of the approach to reliability and availability assessments of large complex systems of this type. The reader is reminded that large complex system operation of the type treated here involves extensive redundancy and results in very complicated models. The models and methods of treatment for this system could form the subject of a very interesting paper. Results through July 1968 on the same program were reported in the document covered by R69-14722.

R70-15160 ASQC 814; 612; 863
Air Force Logistics Command, Wright-Patterson AFB, Ohio. Operations Analysis Office.
RGM-I: EXECUTIVE SUMMARY OPERATIONS ANALYSIS REPORT
Jay F. Williams Jun. 1969 27 p refs
(N69-37244; AD-688823; OAR-9) Avail: CFSTI

The RGM 1 is a life cycle cost model that determines the optimum combination of logistic resources and repair activities for the correction of malfunctions of a hardware system. The model relates the engineering description of the hardware system, and the cost structure and capabilities of the Air Force logistics system, and identifies the repair activities and placement of logistics resource that will maintain the hardware system for the utilization program at a minimum overall cost. The RGM 1 supplies a logical and consistent procedure for determining repair requirements, establishing repair procedures, identifying the resources required, and estimating the life cycle costs involved in hardware support. TAB

Review: This well-written report accomplishes very adequately the intended function of providing a summary description of the RGM-1 computer program. Any person generally familiar with the workings of life cycle costing, cost effectiveness, maintainability, or related concepts should be able readily to grasp from the presentation the general capabilities and limitations of the program. The report states that the program is complete and available to others. Even though certain aspects of the program appear to be peculiar to the Air Force logistics problem (e.g., it was stated that it contains a detailed cost model of the current Air Force logistics systtem), the program, or at least certain features, probably are adaptable to other systems in which unscheduled repair occurs and life cycle costs are a primary consideration. (A modification of the program would be required to include scheduled repair.) Anyone desiring more information on input data requirements, logical structure, problem formulation, and solution procedures for the program should obtain copies of three available AFLC reports, *A User's Guide to RGM-1*, *A Programmer's Guide to RGM-1*, and *The Range Model*, referred to in the report. The respective AD numbers of these documents are as follows: AD-690 522, AD-689 400, and AD-694 075.

R70-15161 ASQC 810; 844
Harvard Coll. Observatory, Cambridge, Mass.
INSTRUMENTATION AND FLIGHT PERFORMANCE OF HCO-NASA AEROBEE 4.185 US HIGH RESOLUTION WAVELENGTH SPECTROMETER
J. Crawford and W. H. Parkinson May 1969 39 p refs
(Contract NAS5-9274)
(N69-38288; NASA-CR-105987) Avail: CFSTI

This report investigates and analyzes the performance of the high resolution wavelength spectrometer and the SPC 324 D/B solar pointing control on NASA Aerobee Flight 4.185 US. Flight evaluation indicates the only system failure to have been in the pointing control. The reasons for this failure are discussed. It is possible, study shows, to prevent future failures of this nature with improved reliability control and more clearly defined lines of authority between Harvard and its subcontractors. An outline of suggested new procedures is enclosed. Author

Review: This report can serve as a reminder to space scientists, engineers, and program managers that the reliability of the payload in space vehicles is no less important than that of the space vehicle. It is written as a post-flight summary of performance of an experiment package. Since there was a failure in the experiment, the discussion is largely devoted to the reason for failure and program changes that would prevent similar occurrences. The report is well-written and interesting to read. The failure is an example of one that could have been clearly avoided had simple and reasonable measures been planned and applied. It is simply a case of the right-hand's not knowing what the left-hand was doing because of inadequate program coordination. Certain remedial measures on reliability control were recommended (they are "ordinary" things that ought to be done anyway). The report is certainly correct in recognizing that the primary responsibility for proper control of reliability rests with overall program management.

82 MATHEMATICAL THEORY OF RELIABILITY

R70-15112 ASQC 824; 844
DIAGNOSIS OF SINGLE GATE FAILURES IN COMBINATIONAL CIRCUITS
Gary D. Hornbuckle and Richard N. Spann (Massachusetts Institute of Technology, Lincoln Lab., Lexington, Mass.) *(Institute of Electrical and Electronics Engineers, International Solid State Circuits Conference, Philadelphia, Feb. 19-21, 1969, Paper* 5 p refs) *IEEE Transactions on Computers*, vol. C-18, no. 3 Mar. 1969 p 216-220 5 refs
Grant NGR-22-009-304
(A69-31112; AD-694895)

Description of two procedures for detecting and diagnosing arbitrary single-gate failures in combinational logic circuits. The testing procedures do not require the construction of a fault table and will locate, to within an equivalence class, the faulty gate and describe its failure. Three test sets of primary input combinations are defined: the detection set, diagnostic set, and complete set. The first procedure uses the detection and diagnostic sets and requires the application of at most $K2^m + K - 1$ primary inputs, where K is the number of gates, each with m inputs. This procedure requires considerable computation for each circuit tested. The second procedure uses the complete set and requires the application of at most $(K - 1)2^m + 1$ primary inputs, and all computation is done once for each circuit type. Author (IAA)

Review: This paper presents a method of detecting and diagnosing single-gate failures in combinational logic circuits and should be of interest to both theoreticians and those engineers engaged in designing input test sequences for digital systems. The authors are among the first to make use of the method presented in the paper for generating input test sequences; however, the procedure appears quite complicated. The major weakness of the paper is the inadequate discussion of the fault model that is employed. According to the authors' definition, a fault is ". . . any detectable transformation of the correct gate function." However, the types of faults that can be detected by the authors' technique seem to be those gate failures which result in either a stuck-at-zero or stuck-at-one gate output.

R70-15114 ASQC 824; 844
DIAGNOSIS OF MULTIPLE FAULTS IN COMBINATIONAL CIRCUITS
Koji Kajitani, Yoshikazu Tezuka and Yoshiro Kasahara (Osaka University, Osaka, Japan) *Electronics and Communications in Japan,* vol. 52-C, no. 4 1969 p 123-131 5 refs

The construction of fault-detection tests and diagnosis procedures to locate decay-type multiple faults which can exist in a combinational circuit are given. Clarification of the properties of such multi-faults is presented and a discussion given of faults undetected when tests are made on the assumption that only a single fault exists. The test input for detecting multi-faults, chosen from the collection of single-fault test inputs, is shown. As a diagnosis and remedy of multi-faults, a gradual repairing method is proposed, which uses repetitive detections. According to this method, the possibility is shown of diagnosing faults very easily with less necessary memory capacity. Author

Review: This paper constitutes a good foundation for the study of the detection and diagnosis of multiple faults in combinational switching circuits. It is directed toward theoreticians and proves several theorems and lemmas which should be useful in the treatment of the multiple fault problem. Much of the discussion is directed toward tree circuits; however, the authors illustrate how the results may be applied to switching circuits in general. Although no algorithm for selecting input tests to detect and diagnose multiple faults is given, the general conditions and restrictions which such a test must satisfy are discussed. The paper appears to be technically sound and is certainly a contribution to the theory of fault detection and diagnosis in digital systems.

R70-15115 ASQC 824; 844
A SYSTEMATIC METHOD OF FINDING DIAGNOSTIC TEST FUNCTIONS
Tadao Ichikawa and Teruji Watanabe (Kokusai Denshin Dewa Co., Ltd., Tokyo, Japan) *Electronics and Communications in Japan,* vol. 52-C, no. 4 1969 p 165-172 7 refs

The method describes the structure of the machines and affords operational analysis for combinatorial logical systems (combinatorial machines) composed of logical-product, logical-sum and negation units. Using this, a method of classifying defective machines systematically, due to stationary binary defects of components, as well as of deriving defect-testing functions mechanically is clarified. Since these processes can all be carried out by computers, a new technique of mechanizing diagnostic operations is established. Author

Review: This is a good paper. The authors have taken an unconventional approach to the problem of detecting and diagnosing faults in combinational circuits; their main objective is to present a procedure for generating input test sequences that could be programmed on a digital computer. In the paper, a machine is represented as a directional graph and the faults considered are stationary (stuck-at-zero or stuck-at-one) failures in the nodes of the graph. The reader should be aware that faulty input branches could cause fault conditions that are not considered in the paper. The technique presented by the authors allows one to derive an input test for detecting prescribed gate failures and the procedure is outlined in the paper. Although the paper is technically sound, more insight should be given regarding the completeness of the proposed testing method. The paper is directed mainly toward theoreticians; however, there is much of practical value included. The novice may find the paper difficult to read.

R70-15117 ASQC 824; 433; 612
Southern Methodist Univ., Dallas, Tex. Dept. of Statistics.
AN OPTIMUM DISCRETE SPACE SEQUENTIAL SEARCH PROCEDURE WHICH CONSIDERS FALSE ALARM AND FALSE DISMISSAL INSTRUMENT ERRORS
Mark W. Smith (Ph.D. Thesis) 16 May 1969 96 p refs
(Contract N00014-68-A-0515; Proj. THEMIS)
(N69-35281; AD-688410; THEMIS-SMU-TR-35) Avail: CFSTI

An optimum sequential search policy is developed for locating an object in a discrete search space assuming a search instrument having both false alarm and false dismissal errors. The search policy obtained specifies that the experimenter always takes his next observation at the potential location which has the largest a posteriori probability of being the true location as computed from the prior probability distribution and previous experimental evidence via Bayes Rule. The results were derived under the following assumptions. A single object is assumed to be located in 1 of N locations and to remain stationary during the search process. The experimenter is presumed to have an initial discrete a priori probability function describing the location of the object. Also available is a single search instrument which the experimenter can employ to examine each of the potential locations. Only one location can be observed at any one time, however. The instrument is assumed to perform a simple, fixed sample size, hypothesis test having known conditional error probabilities of both Type I and Type II. The preliminary decision made by the instrument is thus a noisy decision which is only statistically related to the presence or absence of the object at the location in question. A communication system search example is also considered. Author (TAB)

Review: This is a theoretical paper which deals with an aspect related to reliability engineering as part of the software. It is a topic of interest to engineers but narrow enough to be capable of solution. In order to understand the paper, one needs to know how to apply Bayesian statistics in its elementary form. The detailed mathematics was not checked, but the approach seems quite capable.

R70-15119 ASQC 824; 433
Watervliet Arsenal, N.Y. Benet R and E Labs.
A GENERAL COMPUTATIONAL ALGORITHM FOR BAYESIAN CONFIDENCE BOUNDS, WITH APPLICATION TO THE WEIBULL, LOGNORMAL, AND GAMMA DENSITIES
Richard W. Clarke May 1969 39 p
(N69-35857; AD-688862; WVT-6911) Avail: CFSTI

The general Bayesian concept of random variables is introduced. Application of this concept to confidencing the reliability or safe life of a component is discussed. A computational algorithm which simplifies the calculations and which is applicable to almost any parameter space is presented. The necessary formulas are derived for application to the Weibull, lognormal, and gamma distributional forms. Author (TAB)

Review: This is an applied statistics paper and (without going through the mathematical detail) the mathematics appears to be correct. The beginner may have difficulty with some of the philosophy expressed, and with the way the paper flops back and forth between a continuous and a discrete distribution. Presumably, the author is that way. The author has implicitly decided on equal spacing for the cell intervals on every axis. Whenever one sees an integral sign, it is to be interpreted in the light of a numerical integration. The statement on page 5 ". . . the data used in the analysis will effectively overpower the effects of the original . . . assumption" states the case against the use of Bayesian statistics; for if the original assumptions are overpowered by the data, there was no point in making any of the original assumptions and one might just as well have used the classical confidence approach. The author also suggests using a uniform prior distribution (in discrete space). Generally speaking, if one makes the prior assumption which is equivalent to assuming complete ignorance, the results will be equivalent to using the classical confidence approach. Therefore, from the author's discussion, it is difficult to see why one should be using the Bayesian statistics when it complicates matters. There are arguments for using it, but the author has not given them.

R70-15121 ASQC 824; 844
Royal Aircraft Establishment, Farnborough (England).
FATIGUE LIFE ESTIMATION UNDER SPECIAL LOADING SPECTRA BY MEANS OF VARIABLE AMPLITUDE FATIGUE STRENGTH DATA OBTAINED WITH STANDARD SPECTRA [DIE LEBENSDAUERABSCHAETZUNG BEI SONDERKOLLEKTIVEN NACH BETRIEBSFESTIGKEITSVERSUCHEN MIT EINHEITSKOLLEKTIVEN]
H. O. Stermann May 1969 20 p refs Transl. into ENGLISH from ICAF Doc. 425, German Report TB-80
(N69-37287; RAE-LIB-TRANS-1357; TB-80) Avail: CFSTI

The various fatigue loading spectra which occur in service are summarized and examples are given to illustrate the sensitivity of fatigue strength to spectral shape. The difficulties inherent in the prediction of fatigue strength under certain special loading spectra are discussed, and a new life prediction technique is proposed based on the use of universal fatigue strength data obtained under a number of standard block program loading spectra. An example using notched specimens in AlCuMg2 shows good agreement with experimental results, but further work will be necessary before the applicability of the techniques can be fully assessed. Author

Review: This is largely a theoretical paper. It is concerned with approximating a random load spectrum by several standard random load spectra. In one case, a uniform distribution is combined with a Gaussian distribution, and in the other case, three Gaussian distributions are combined. These two methods can approximate quite well most any reasonable spectrum encountered in practice. It will be necessary to obtain fatigue data under these standard conditions in order that they can be combined for prediction purposes. A linear cumulative damage law is used for combining these spectra. This is considered to be much better than

using the linear cycle by cycle. The paper will have value largely for theorists and those research-minded experimentalists who are seeking to verify theories. Random loading is an important innovation in fatigue testing, and of course, fatigue is a major mechanism of failure in aerospace structures.

R70-15122 ASQC 824; 433
Aerospace Corp., El Segundo, Calif. Engineering Science Operations.
THE PREDICTION OF OPERATIONAL SUCCESS, SEPTEMBER 1966 - DECEMBER 1967
Joseph W. Duroux 16 Jun. 1969 41 p refs
(Contract F04701-68-C-0200)
(N69-37748; AD-689748; TR-0200(4306-01)-3; SAMSO-TR-69-185) Avail: CFSTI

A general procedure for obtaining a direct estimate of confidence in the success of a process is developed. The measure of confidence is an expected value of reliability based on a Bayesian a posteriori distribution. A flexible model of the a priori distribution permits the combination of a priori estimates with the results of either attribute (success or failure, or variate (measurement) testing). A self-contained applications section summarizes the methods of computation. Author (TAB)

Review: This is a tutorial paper on the Bayesian approach and can be read profitably by anyone with even a very modest understanding of statistics, but it is not suitable for starting from scratch. The philosophic foundation is well given, and although every equation was not checked in detail, they appear to be accurate. The report will be of most value to designers and reliability engineers since statisticians will have access to more direct treatises on the subject. Any of the former category who are not familiar with the Bayesian approach would do well to look up this paper if they have no other handier source of learning about Bayesian approach.

R70-15124 ASQC 822
Weibull (Waloddi), Lausanne (Switzerland).
A CRITERION FOR THE ACCEPTABILITY OF ASSUMED DISTRIBUTIONS Summary Report, Feb. 1968-Dec. 1969
Waloddi Weibull Wright-Patterson AFB, Ohio AFML Apr. 1969 39 p refs
(Contract AF 61(052)-943)
(N69-37173; AD-689406; AFML-TR-69-124; TSR-9) Avail: CFSTI

The usual way to solve the fundamental problem of deciding whether an assumed distribution function is acceptable or not, consists - if at all done - in estimating the parameters and checking the attained goodness of fit by some accepted criterion, in most cases the Chi-square test. In this way, the decision depends not only on the assumed function, so it may happen that an acceptable function may be rejected on the basis of results from poor estimating or fitting procedures. The purpose of this research was to find a criterion which eliminates such fatalities and depends entirely on the assumed function alone. Such a criterion, based on the number-of-runs has been proposed. The properties of this statistic and its usefulness is a measure of departure from the true distribution have been demonstrated. The concept maximum number of runs (MAXNOR) of a given sample and methods for its ascertaining have been introduced. Its use as a criterion for deciding whether the assumed function is acceptable or not has been studied by applying it to data from tests on strength of brittle materials, fatigue life of aluminum alloys, etc. Author (TAB)

Review: This is an important topic in statistics and particularly in reliability. The author applies his method to some fatigue data as one of the examples; otherwise, it is a theoretical paper. As such, its meaning is much more accessible to statisticians than it will be to the ordinary reliability engineer. The method appears to be of sufficiently widespread importance that it should be given wider distribution, especially in a form which is more suitable for cookbook use by engineers. (The mathematics was not completely checked, but it appears to be competent.) On page 4, it is stated "(if the assumed function involves c parameters, it is always possible to let the curves intersect in c points.)" It would seem that this statement will not always be correct, especially if one is thoughtless in his choice of an assumed median curve.

R70-15125 ASQC 822
Georgia Univ., Athens. Dept. of Statistics.
AN APPLICATION OF STATISTICS IN MIXTURE OF EXPONENTIAL DISTRIBUTIONS
H. I. Patel May 1969 14 p refs
(Contract NAS8-11175)
(N69-34959; NASA-CR-61292; Rept-61292) Avail: CFSTI

This paper is concerned with a distribution of an order statistic when a sample of n is composed of n sub 1 observations. In particular the expected value of the nth order statistic has been obtained when the sample is composed of two types of components and when it is composed of three types of components. The distribution of the nth order statistic in the most general situation has been obtained. A small application to cost analysis of ore samples is mentioned. Author

Review: This paper deals with a small statistical problem shown to be of interest in reliability/maintainability aerospace situations. It will be of value largely to theoreticians who ought, at least, to remember that this paper exists, and thus have the results available when they are needed. The mathematics was not checked in detail, but it appears to be competent.

R70-15137 ASQC 824
Watervliet Arsenal, N.Y. Benet R and E Labs.
MAXIMUM LIKELIHOOD ESTIMATION OF DISTRIBUTION PARAMETERS FROM GENERALLY CENSORED SAMPLES
Royce W. Soanes, Jr. Jun. 1969 18 p ref
(N69-38435; AD-690185; WVT-6923) Avail: CFSTI

A simple derivation of the likelihood function for generally censored samples is given, where 'generally censored sample' connotes: a set of failure data containing both failures and survivors with various different tentative survival times. Author (TAB)

Review: This paper has an intriguing title since it treats a subject of special importance in the theory of life testing and thus is potentially valuable to reliability engineers. The mathematical formulation of the problem is extremely general, however. It does little more than put the statement of the problem into mathematical function notation and, just about then, the paper ends when the subject is beginning to be interesting. There are no examples using particular distribution functions nor methods which indicate what kinds of approximations might be used to solve the problem. Therefore, the paper is mainly of value to theorists who do not wish to take the time to formulate the problem but wish to go on from the endpoint of this paper using their own density functions. The report will be of value only to statisticians who are competent enough to carry the work further.

R70-15139 ASQC 821; 546

National Aeronautics and Space Administration. Goddard Space Flight Center, Greenbelt, Md.

THE X SUP 2 STATISTIC AND THE GOODNESS OF FIT TEST

Peter D. Argentiero, Robert A. Morris (Md. Univ., College Park) and Robert H. Tolson (NASA. Langley Res. Center, Langley, Va.) Washington Jun. 1969 134 p refs
(16-21-12-03-51)
(N69-30610; NASA-TR-R-313) Avail: CFSTI

The probability density function of the X_2 statistic is derived. The applicability of the X_2 statistic to goodness of fit tests and its approximation by the chi-square variable are discussed in some detail. Tables of critical values of the X_2 statistic are provided for a range of sample sizes N and equiprobable categories K which prove useful in goodness of fit tests. An example is given to demonstrate that the proper application of tables of critical values of X_2 can add considerable precision to a goodness of fit test when small samples are involved. Author

Review: Testing the goodness of fit of the data to a supposed distribution is an important activity in the field of reliability statistics (as in many other fields). This paper will be of value to statisticians rather than reliability engineers since the discussion presumes at least a modest amount of statistical background. Just as chi square is the sum of squares of standardized *normal* variables, X_2 is the sum of squares of standardized binomial variables (standardizing means that the variable has been linearly transformed to have zero mean and unit variance). Chi square and X_2 are equivalent when the sample size for the binomial variables is "made infinite." The application of X_2 in this paper is to the goodness-of-fit test in a manner more exact than–but analogous to–the customary application of chi square. It is worthwhile emphasizing the difference between the X_2 statistic and the chi-square statistic; and the authors have generated a great number of tables in order to be able to use this X_2 statistic. (Since a capital X is often used in place of the chi, one has to keep remembering while reading the paper that it is a capital X he is looking at and not a chi.) Some of the pages do not reproduce well so that copies of the report may be difficult to use. By far the largest portion of the report is taken up with the tables of the X_2 statistic. For rough-and-ready tests, few statisticians will want to take the trouble to use this more exact method; however, it is not unreasonable to suppose that often one will wish at least to see roughly what error is caused in making the usual chi-square approximation. These tables will be a big help in that regard.

R70-15143 ASQC 824

A PREDICTION INTERVAL TO CONTAIN A FUTURE SAMPLE FROM A NORMAL POPULATION

Gerald J. Hahn (General Electric Co., Research and Development Center, Schenectady, N.Y.) *Evaluation Engineering,* vol. 9, no. 2 Mar.-Apr. 1970 p 19-21 8 refs

Prediction interval is defined as one that contains all the value for future sample, based upon the results of a past sample. The procedure of constructing a two sided prediction interval and additional information concerning such intervals are discussed. It is noted that prediction intervals are of interest to manufacturers of large systems, or to purchasing agents concerned with performance of a small number of units. Author

Review: This paper performs a useful service in two ways. First of all, it explains prediction intervals and brings them to the attention of reliability engineers. Whether reliability engineers like it or not, statistics is a useful language for them. Second, it explains how one calculates this prediction interval (assuming a Gaussian distribution) and gives references which show how to make the calculation for other distributions. The paper will be difficult reading for those who are not at least modestly familiar with elementary statistical concepts, but if it is read several times and the numerical example followed closely, they will be able to understand it. The table itself was not checked since no algorithms for generating it were given in the paper. However, the same tabulation was included in a previous article in a referred journal. The more extensive tabulation was in an article by the author which appeared in the September 1969 issue of the Journal of the American Statistical Association (vol. 64, pp. 878-888) entitled "Factors for Calculating Two-Sided Prediction Intervals for Samples from a Normal Distribution" and which also provided the theoretical justification for these tables. The purpose of the present paper is to draw these methods to the attention of a much broader audience.

R70-15151 ASQC 821; 431; 831

NEW RESULTS IN EFFECTIVENESS PREDICTION FOR MARKOVIAN SYSTEMS

C. T. H. Lee and A. Dushman (Dynamics Research Corp., Wilmington, Mass.) *In: Proceedings of the 1970 Annual Symposium on Reliability, Los Angeles, Feb. 3-5, 1970* Symposium sponsored by the Institute of Electrical and Electronics Engineers, Institute of Environmental Sciences, American Society for Nondestructive Testing, and American Society for Quality Control New York IEEE, Inc. 1970 p 410-419 10 refs

A unified approach is formulated for obtaining many measures of system effectiveness: instantaneous availability, reliability, interval reliability, steady state availability, mean time-to-first-system-failure, system mean up-time, and system mean down-time. Matrix formulas for the measures of system effectiveness are developed. The system mean up-time is shown to be a special case of the mean time-to first-system-failure. The concept of viewing the Markov process of a Markovian system as an imbedded Markov chain together with exponential holding time at each system state is employed to simplify the computation of the system mean up-time and mean down-time. A computer program for computing these mean times is presented. Author

Review: In this paper, Markov chains in continuous time, with a finite number of states, and with temporally homogeneous transition rates are used as models for complex systems. Various measures of system effectiveness are investigated including availability and reliability and, in particular, mean up-time and mean down-time. The transition probability matrix is derived for a general homogeneous Markov system and then the system is specialized to a four-state category model in studying the various measures of system effectiveness. Since the measures generally involve evaluating infinite series of matrices, a computer program (in Fortran IV) is given which does the evaluation for the mean up-time and mean down-time. The paper is mathematically sound, although many of the manipulations are classical in the study of homogeneous Markov processes. There are new results, namely those concerning the mean time-to-first-failure from which the system mean up-time is computed. This work can be of interest to theoreticians as well as applied systems analysts who wish to look at complicated systems through a Markov process framework. A sound knowledge of Markov processes and reasonable sophistication with mathematics are essential to a thorough understanding of this paper.

R70-15153 ASQC 824

ASSESSING COMPONENT LIFE FROM FIELD SERVICE TESTS

Paul E. Ashley (Sperry Flight Systems Div., Phoenix, Ariz.) *In: Proceedings of the 1970 Annual Symposium on Reliability, Los Angeles, Feb. 3-5, 1970* Symposium sponsored by the Institute of Electrical and Electronics Engineers, Institute of Environmental Sciences, American Society for Nondestructive Testing, and American Society for Quality Control New York IEEE, Inc. 1970 p 436-440

A method of assessing wearout life from field service tests was developed and is easily adaptable to a variety of components. It is stated that if the wearout distribution can be assumed with sufficient accuracy, a lower one sided confidence limit for the wearout mean can be computed from appropriate field service data, even before any wearout failures occur. With a sufficiently large sample, it is noted that successive periodic predictions of the wearout mean approach a final value, usually before the high time unit reaches half this final value. A design with insufficient life becomes apparent quickly, and corrective action is executed. If the predictions indicate that the wearout mean substantially exceeds the original design goal, the period between overhauls can be extended, usually before the high time unit has reached the original overhaul time. Author

Review: This paper is not clear and suffers from poor editorial work. Examples of the difficulties are the following. (1) The equation at the bottom of column 1, page 436, is presumably a probability density function; the only unknown in it is defined to be the standard deviation, and apparently it is the only parameter of this distribution to be evaluated. But in that case, the equation following equation 2 does not make sense. (2) Some of these early equations are further confused by the statement near the bottom of column 1, page 436, "The wearout failure histograms of these designs were roughly approximated by a normal distribution with the standard deviation equal to one-half the mean, even though the means varied widely." This is about the last we hear of the *normal* approximation. (3) It is very likely that the author has incorrectly defined s; apparently s is not the standard deviation but is the random variable, and the random variable is related to the actual failure times by dividing each time by a normalizing factor. This normalizing factor is presumably one-half the true mean and is the unknown parameter. (The author privately substantiated this interpretation, with the added information that the variance of s is 1.) (4) Apparently the reliability function is presumed to be the product of two tractable reliability functions. It is not clear in what sense the term "biased wearout distribution" is used. It is not clear how one decides whether an individual gyro has failed by wearout or by chance or if it makes any difference in evaluating the two parameters. (The author privately pointed out that it is usually possible to assign the failure classification–chance vs. wearout–by inspecting the failed unit.) Thus, while it is possible to combine two distributions (as has been suggested many times in the literature) this paper is not a clear statement of the method which is presumably used due to the ambiguities in nomenclature and exposition. With the additional information supplied by the author, the paper is more clear and generally is a straightforward useful application of standard statistical techniques.

R70-15154 ASQC 824; 551

NONPARAMETRIC RELIABILITY AND ITS USES

R. K. Hood and E. P. Virene (Boeing Co., Seattle, Wash.) *In: Proceedings of the 1970 Annual Symposium on Reliability, Los Angeles, Feb. 3-5, 1970* Symposium sponsored by the Institute of Electrical and Electronics Engineers, Institute of Environmental Sciences, American Society for Nondestructive Testing, and American Society for Quality Control New York IEEE, Inc. 1970 p 441-448 6 refs

A nonparametric method for determining reliability and its associated confidence is presented. Examples of the application of this method to numerical data, a table to facilitate nonparametric computation of reliability, and a mathematical model in support of the nonparametric statistics are shown. Loss in statistical efficiency is considered and can be serious when the exponential distribution is in fact valid for the life test situation. How the nonparametric method performs is compared to the use of a method based on the exponential failure frequency distribution, when in fact some distribution other than the exponential validly describes the missions or operating life times to failure under study. Author

Review: This paper apparently makes use of the fraction of the population that can be expected to exceed the lowest of n in an ordered sample. It could be extended to give the fraction of those which would exceed the *kth* item in an ordered sample of n. Since the value (usually of time) that can be considered is a random variable rather than a fixed one, the application of these formulas is subject to the vagaries of the data. Unfortunately, the authors do not give the formula used to generate the table, so it cannot be checked. Regardless of the above statements, the method appears to be statistically valid and should be included in the repertoire of a reliability statistician.

R70-15158 ASQC 821; 551

Purdue Univ., Lafayette, Ind. Dept. of Statistics.

SOME SELECTION PROCEDURES WITH APPLICATIONS TO RELIABILITY PROBLEMS

Shanti S. Gupta and Gary C. McDonald (Gen. Motors, Detroit) Jun. 1969 12 p refs *Its* Mimeograph Ser. No. 196
(Contract Nonr-1100(26))
(N69-40462; AD-691803) Avail: CFSTI

The paper studies some ranking and selection procedures (also called multiple-decision procedures) which lend themselves to applications in reliability problems. Some of the procedures discussed are in a sense distribution free, while others assume a specific distributional form of the underlying observations. In addition, a parametric procedure for selecting a subset containing the gamma population with the largest guaranteed life is introduced. A comparison is then made between this parametric procedure and several others which are based on the ranks of the observations. This comparison is in terms of the expected number of population included in the selected subset. Author (TAB)

Review: The selection procedures described in this paper are those for choosing a subset containing the best of several populations or treatments (where *best* is defined in each individual case). The results of this paper may not be totally understood by the ordinary reliability engineer, who may have to consult a statistician when he first uses one of these procedures. The statistics was not checked in its entirety, but it appears to be competent. The problem with which the paper deals is a real one, and effort should be made to make the results more suitable for direct use by reliability engineers. Some of the references in this work contain the tables of constants required for the actual implementation of the discussed procedures, and the authors supply a short table of constants needed for selecting a subset containing the gamma population with the largest guaranteed life.

R70-15167 ASQC 821

STATISTICAL DISTRIBUTION OF THE MECHANICAL PROPERTIES OF CAST COMPONENTS

N. A. Kostenko *Russian Engineering Journal*, vol. 49, no. 2 1969 p 13-16 7 refs

A method for determining the distribution of the strength of cast components is proposed. The strength of the housings of shock absorbers in a device used for joining railway tracks is analyzed. The variation in the mechanical properties of these castings is caused by the scatter in the material properties occurring in a single or in several casting batches. The type and the parameters of the distribution are evaluated by a method of testing a number of samples obtained from the parts being evaluated. For solving this problem, it is necessary to evaluate the scatter, the mean value of the tensile strength, and the type of distribution. Author

Review: The main value of this paper is in bringing to the attention of designers the fact that the properties of cast components are rather non-uniform and that it is wise to take into consideration the statistical distribution of their strengths. Since, in many cases, strength is inferred from hardness measurements, the paper shows the relationship between strength and hardness. There is naturally much scatter in this relationship and it is not clear that the paper has handled it properly. Another difficulty with the paper is the use of the theory that the probability of failure in a volume is proportional to the size of that volume. While this is nominally true for brittle materials (in principle, the relationship would define a brittle material), it is not clear that the cast steels being tested do in fact follow this relationship. While the calculated value of reliability for one year is asserted to agree closely with the experimental values, the calculated probability of failure is 1% and the experimental range is presumably 1.5 to 3%. Since there is no indication of how the theoretical or experimental values were determined, it is again not clear whether they agree reasonably well or not. Nevertheless, the paper does have an important message for those who were not familiar with it before, namely, that all materials, and especially castings, do have considerable variations in their strength properties. They are due not only to variations in chemical composition but to lot-to-lot variations as well. They should be taken into consideration in the calculation of the reliability of mechanical components.

83 DESIGN

R70-15111 ASQC 830; 844

Texas Univ., Austin. Electronics Research Center.

DISTINGUISHABILITY CRITERIA IN ORIENTED GRAPHS AND ITS APPLICATION TO COMPUTER DIAGNOSIS, PART 2

W. Mayeda and C. V. Ramamoorthy 21 Feb. 1969 23 p refs
(Grant AF-AFOSR-0766-67)
(N69-37868; AD-690127; TM-6; AFOSR-69-0643TR) Avail: CFSTI

In a previous paper (AD-685 739) the authors considered the application of graph theory to the problems in computer diagnosis. In particular the distinguishability criteria in directed graphs is developed and bounds on the number of test points needed to locate faults in a sequential system are derived. In the present paper it is shown that a system can also be diagnosed by means of test gates which block or unblock the flow of output signals at selected points in the system. In particular the distinguishability criteria in directed graphs is developed using only test gates, and bounds on the number of test gates needed to locate faults in a sequential system are derived. Since implementing test gates is vastly easier and cheaper than inserting and monitoring test points, the schemes proposed and results developed appear to be of practical significance. Author (TAB)

Review: Numerous techniques are evolving for automatic fault detection and isolation of complex logic circuits. This report describes a particular technique (using "test gates") for sequential circuits and develops and proves several basic theorems related to it. It is highly theoretical and requires very meticulous reading to grasp all of the details. Even though the notation draws from an earlier report by the same authors and is not defined explicitly in this report, the meaning of most of it is eventually grasped as one follows the text in detail. The mathematics was not checked but appears competent. The results presented in the report are significant and will certainly be of interest to persons working in automatic fault detection and isolation. Results given are conclusive; however, the authors indicate future work to be done. No mention was made of the effect of possible faults of the "test gates" themselves and practical applications of the technique will certainly require that this be considered.

R70-15113 ASQC 830; 782

PROTECTION OF ELECTRONIC EQUIPMENT AND MEASURING SYSTEMS FROM EXTERNAL INTERFERENCE: REVIEW

K. E. Erglis *Instruments and Experimental Techniques*, vol. 3 1969 p 541-552 refs Translated into ENGLISH from Pribory i Tekhnika Eksperimenta (Moscow), no. 3, May-June 1969 p 5-17

The origin of interference pulses and the paths by which they propagate, represented in the form of equivalent electrical circuits, are discussed. The parameters of these equivalent circuits are discussed, specifically the inductance of the return conductors in the transmission lines: conductors of round cross section, a conducting plane, and a coaxial shield. Measures necessary to shield the network against interference originating in the equipment, and measures for the protection of sensitive instruments and modules affected by radio-frequency interference affecting the power supply network, are recommended. Ways of utilizing L-shaped filters with band-stop filter choke coils to good advantage in interference suppression applications are demonstrated. Features of the design of power networks and illumination networks aimed at minimizing radio-frequency interference fields are discussed. Power induction noise, induced by external fields on a variety of transmission lines conveying useful information, also comes under discussion. Optimum configuration and structure are proposed for: a laboratory power network, grounding, and information-conveying connections in an extended branched measuring system. Author

Review: Even though the discussion in this paper is primarily narrative, it can benefit anyone, from the novice to the experienced, who is concerned with the analysis or reduction of RF interference. It gives good, elementary descriptions of various sources of RF interference (but does not cover induction pick-up) and presents some very sound, practical design advice for suppression. The discussion focuses on laboratory-type equipment, but the concepts can apply equally well to flight systems. Reading becomes a little awkward at times due probably to the translation; however, this does not significantly detract from the technical worth of the paper. Some of the terminology also differs from that commonly used by engineers in the U.S.; however, the meaning throughout is quite clear. Another good reference for practical information on RF interference is a two-volume handbook set covered by R66-12745

R70-15116 ASQC 838
RELIABILITY OF ADAPTIVE REDUNDANT STRUCTURES WITH A VARIABLE RESTORING ELEMENT THRESHOLD
S. M. Domanitskii *Automation and Remote Control,* no. 6 1969 p 972-980 2 refs Translated into ENGLISH from Automatika i Telemekhanika (Moscow), no. 6, June 1969 p 157-166

Using M-diagrams, the change in the states of the redundant structure is investigated for two types of damage to the functional blocks. It is demonstrated that in the presence of damaged blocks the variation of the threshold of the restoring element according to a specified algorithm permits reliability to be increased over that of nonadaptive structures. Author

Review: The problem treated in this paper is significant to persons concerned with improving the reliability of logic circuits. The restoring element typically represents a majority voter for which the voting logic is adaptively modified to compensate for known failed inputs. The approach represents a variation of the adaptation principle presented earlier by W. H. Pierce in a paper covered by R67-13225. The paper is generally well-written and the translation (from Russian) is quite good. Extensive mathematics is used in the derivation and was not checked in detail, but it appears competent. Anyone wishing to use the results ought to follow through the derivation in detail. One point of confusion occurs early in the paper in a definition of the threshold function; it appears that in the third paragraph on the second page "$y \equiv 0$" should be written as "$y_j \equiv 0$." It is worthy of mention that the reliability expression derived treats only one of several possible adaptation algorithms. The author states that a later paper will treat the problem of determining the optimum algorithm. Persons concerned with the problem will do well to be on the lookout for this later paper.

R70-15127 ASQC 831; 814
National Aeronautics and Space Administration. Goddard Space Flight Center, Greenbelt, Md.
SPACECRAFT PERFORMANCE ANALYSIS
C. V. Judge, P. A. Villone, and W. A. Mecca May 1969 49 p refs
(N69-30821; NASA-TM-X-63593; X-260-69-202) Avail: CFSTI

The performance lives of a random sample, and of one year design spacecraft, are examined in an effort to provide information concerning useful life of a spacecraft system exclusive of experiment performance. Author

Review: This report catalogs spacecraft performance to indicate useful life for amortization purposes. Failure criteria are established with overall vehicle life in mind rather than from the point of view of an individual experiment. The data are clearly presented and sufficient indication is provided as to how the calculations were made. The report summarizes significant observations from the data in lieu of conclusions. It is of interest over and above the original (amortization) purpose in that researchers who are planning experiments will find qualitative value in the catalog of launch and failure data for sample Goddard satellites.

R70-15134 ASQC 830; 612; 844
National Aeronautics and Space Administration. Ames Research Center, Moffett Field, Calif.
A DETAILED STUDY OF MANUAL BACKUP CONTROL SYSTEMS FOR THE SATURN 5 LAUNCH VEHICLE
Gordon H. Hardy, Richard L. Kurkowski, Ronald M. Gerdes, Glen W. Stinnett, and Glen D. Ritter (NASA. Marshall Space Flight Center) Washington Jun. 1969 58 p refs
(N69-28018; NASA-TN-D-5261) Avail: CFSTI

A detailed study was made of manual backup control systems suitable for the first stage of the Saturn 5 launch vehicle. A technique to measure the manual control system reliability with a piloted simulator was developed. Two manual backup control systems were considered: a load relief and a no load relief system. Both systems allowed the pilot to close an adaptive control loop that is parallel to the primary automatic control system. The system failure modes associated with the primary system, as well as those associated with the additional hardware for the piloted backup system, were considered. An analog piloted simulation was used and included rigid-body, engine-actuator, vehicle-bending, propellant-sloshing, and control-system dynamics. Over a thousand simulated flights with randomly selected failures were made with three research pilots. The results indicate that for the failure modes and automatic system considered, the piloted manual backup system can reduce the probability of mission failure by a factor of 2. Trajectory dispersions at first-stage cutoff were significantly reduced. The hand-controller and pressure-suit configurations had little effect on system performance. Author

Review: This report is both well written and well organized. It gives the methodology and results of a Monte Carlo simulation of piloted flight of the first stage of the SATURN V launch vehicle. The objective of the study was to determine if the probability of mission success can be improved by incorporating a pilot in a back-up mode to the primary automatic control system of the SATURN vehicle. The approach was to allow the pilot to take over control of the vehicle, by relying on the appropriate displays, while random failures were simulated in the primary control system. A detailed discussion of the simulation, the assumptions, and the types of failures studied is given. The study revealed those failures for which the pilot can effectively compensate as well as those failures for which the pilot was found to contribute little toward improving system reliability. Although the study was of a specialized nature, the methodology may prove useful for completely unrelated investigations.

R70-15135 ASQC 838; 823
Institute of Electrical and Electronics Engineers, New York. Computer Group Repository.
FAILURE OPERABLE REDUNDANT NAND NETWORKS
Tadao Ichikawa (Kokusa, Denshin Denwa Co., Ltd., Tokyo, Japan) and Teruji Watanabe (Kokusa, Denshin Denwa Co., Ltd., Tokyo, Japan) [1969] 45 p refs
(R-69-148)

In order to obtain a kind of redundant NAND network, consideration is given to a standardized tree network which has all possible connections preserving complete symmetry. A method is proposed of assigning such input symbols to the input terminals of the network that can yield a desired function at the output of the network. A mechanical procedure is given for deciding direct correspondencies between input symbols to be assigned and input terminals of the network. A way to give the network a decomposed-structure which is easy to diagnose is given. As to the redundant network thus obtained, its normal behavior can be recovered only by changing the assignment of input symbols even if some elements of the network become faulty. Some fundamental considerations on the ability of this failure-recovering are made, and the way of reassigning input symbols is clarified. Author

Review: This interesting paper is oriented mainly toward theoreticians. A redundant NAND configuration is presented which

can be made to realize a given switching function by the proper arrangement of input and bias signals. Additionally, the network possesses the capability to recover from a failure by the proper reassignment of circuit inputs. This redundant network takes the form of a standardized tree in which all branches eventually lead to a single output node. Although one immediately becomes suspicious of any reliability claims for such a network, the results of this study appear to be quite general. The authors' concept involves the diagnosis of logical failures and subsequent reassignment of the circuit inputs in order to preserve the desired output. Some consideration is given to fault diagnosis, mainly by clarifying the way of partitioning a given circuit to make the diagnosis easier. The technique of recovering from a failure is emphasized and an algorithm for making the necessary reassignment of circuit inputs is given. Little consideration is given to the practical aspects of the technique. The paper is somewhat difficult to read, perhaps due to the authors' not writing in their native tongue.

R70-15136 ASQC 830; 821
Institute of Electrical and Electronics Engineers, New York. Computer Group Repository.
ON THE SYNTHESIS OF FAIL-SAFE LOGICAL SYSTEMS
Yoshiyori Urano (Waseda University, Tokyo, Japan) and Teruji Watanabe (Kokusai Denshin Denwa Co., Ltd., Tokyo, Japan) [1969] 58 p refs
(R-69-141)

A binary (0, 1) fail-safe logical system is defined and its structure is examined. The necessary and sufficient conditions are derived, and the concept of a ϕ fail-safe logical system is introduced. It is shown that the system has many advantageous characteristics for high reliability or high availability. As an example, the single rail (double rail) logical system with three levels, 0, Φ, and 1, is discussed in detail. The Φ_m fail-safe logical system is investigated from the viewpoint of multivalued, (ternary) logics. The ideas suggested are applicable to the case of sequential logical systems too. Author

Review: This paper is directed primarily toward theoreticians. It consists largely of a series of theorems and corresponding proofs which set forth some of the properties and conditions for realizing fail-safe logic circuits. The authors examine and formally state the properties of logic circuits which fail-safe at logical ZERO or ONE as well as a so-called Φ logic circuit which fails safe at an output state which is neither ZERO nor ONE. The paper is more concerned with the conditions for realizing such circuits than with a procedure for synthesis. Although the paper is of a theoretical nature, the authors give some consideration to the practical aspects of achieving fail-safe logic circuits. The newcomer to this field may find some difficulty in reading the paper.

R70-15140 ASQC 831; 824
RAND Corp., Santa Monica, Calif.
RELIABILITY OF AIRCRAFT AS DETERMINED BY OPERATIONAL FIELD TESTS: THE NEED FOR PROPER TEST DESIGN AND DATA REQUIREMENTS
Chauncey F. Bell Apr. 1969 17 p Presented at NATO Conf. on the Appl. of Operational Res. to Reliability, Turin, 30 Jun.-4 Jul. 1969
(N69-30964; AD-686414; P-4054) Avail: CFSTI

The paper is concerned with complete aircraft systems, such as tactical fighter squadrons and intratheatre (or airline) transportation systems. Industry on the one hand, and operators (airlines, military services) on the other, are faced with the problem of agreeing to specifications concerning reliability and maintainability, validating these specifications in the finished product and deciding what value to attach to reliability and maintainability. The problem of validation is particularly elusive. Laboratory or subsystem tests provide one set of figures. Different airlines using the same equipment experience different reliabilities. The same military aircraft type behaves differently at different bases, or when flying different mission types. Apparently satisfactory planning factors for procurement of spare parts, or maintenance manpower, turn out to be at wide variance with the requirements generated in operational environments. Author (TAB)

Review: This enlightening paper is concerned with the application of operations research to the problems or reliability assessment of aircraft and has broader usefulness than the title might suggest. The author has oriented the paper toward policy-makers rather than reliability engineers; he is concerned that policy-makers do not always employ the proper methods in arriving at reliability decisions. The author's objectives are: (1) to provide an insight into the matter of the wide variances reported on the reliability of apparently similar or identical equipment and (2) to develop a methodology of designing improved operational tests. There is much worthwhile information in the paper. In particular, the discussion on the probable causes of the previously mentioned wide variances indicates some pitfalls that might be avoided in making reliability decisions. This is a well organized, well-written paper which should benefit those who make decisions regarding the type and significance of reliability measurements.

R70-15147 ASQC 838
A REDUNDANCY ANALYSIS TECHNIQUE
A. E. Spindler (Honeywell, Inc., Communications and Data Products Div., San Diego, Calif.) *In: Proceedings of the 1970 Annual Symposium on Reliability, Los Angeles, Feb. 3-5, 1970* Symposium sponsored by the Institute of Electrical and Electronics Engineers, Institute of Environmental Sciences, American Society for Nondestructive Testing, and American Society for Quality Control New York IEEE, Inc. 1970 p 181-185

Computerized redundancy analysis techniques are described. Procedures for selecting redundant configurations that increase optimization with respect to cost, size, weight, volume, and other tradeoff parameters are discussed. The basic steps are listed: definition of a nonredundant channel, monitor interfaces, and building block parameters; formation of the axes and system, and the selection of the system. It is stated that these techniques are applicable to any redundancy analysis problem. Author

Review: The author's objective to ". . . describe the computerized redundancy analysis techniques that are made available to you by the PAR technical report . . ." is only nominally achieved. The descriptions are sufficient to give a general idea of what PAR will do, but potential users will want many more details. But he does achieve the secondary objective of encouraging the reader to investigate these PAR techniques. Unfortunately, from the paper one cannot judge exactly what the PAR techniques do *vis a vis* what the engineer preparing the problem must do. It is not clear what kinds of redundancy the situation creates and then proceeds to analyze or if the engineer must form each redundant configuration he wants to have analyzed. One ought to investigate the original report to see wherein it can be of value. (The author identifies the report by title and an Air Force Flight Dynamics Laboratory number only–he does not name the authors, give an AD number for the report, nor say exactly how copies can be obtained.)

R70-15157 ASQC 830; 844

Institute of Electrical and Electronics Engineers, New York Computer Group Repository.

CODING TECHNIQUES FOR FAILURE TOLERANT COUNTERS

I. S. Reed (Univ. of Southern Calif., Los Angeles, Calif.) and A. C. L. Chiang (Litton Industries, Woodland Hills, Calif.) 1969 12 p refs

(Contract DA-ARO-D-31-124-G929)

(R-69-158)

The application of a modified first order Reed-Muller code and the perfect Hamming code to the design for failure tolerant counters is discussed. The first code employs a majority element for implementing the error correcting scheme while the last one makes use of a variable majority element. These coding techniques can be applied in principle to other logic hardware to increase its reliability. Author

Review: This is a well written paper which clearly illustrates the application of error correcting codes to achieve a counter state assignment which results in the proper state transitions even with a limited number of faulty memory elements. Majority voting is employed to combine the information and check digits to assure the proper state transitions. A brief review of coding theory is given to make the paper essentially self-contained. Although the paper is mainly concerned with failure tolerant counters, it is explained in sufficient detail to have application to general sequential machines. The paper is not concerned with predictions of the increased reliability resulting from the application of a coding scheme. The mathematics was not checked completely, but it appears to be correct. The authors have presented the material in an exceedingly practical manner. The paper will be of value to engineers interested in the design of reliable digital systems.

R70-15162 ASQC 838; 824

RELIABILITY ANALYSIS OF A REDUNDANT SYSTEM

Hisashi Mine, Shunji Osaki, and Tatsuyuki Asakura (Kyoto University, Kyoto, Japan) *Electronics and Communications in Japan,* vol. 52, no. 4-C 1969 p 175-176 3 refs

Analysis of the two out of n system is presented. This system consists of n (n greater than two) units, and the system down condition occurs when two out of the n units are malfunctioning. The assumption is made that malfunction of each unit is independent and repairable. Laplace-Stieljes transformation is obtained when all units are put into operation at the time t equals zero. Author

Review: This is a mathematical paper and, as the authors have been doing in various articles, uses the Laplace-Stieltjes transform for solving the problem. Since transform methods are used and one of the distributions is arbitrary, the distribution of time-to-initial-failure is given only by its transform. The average time can be obtained from that expression and is done in the paper. This is not a major contribution to the theory of redundant systems, but occasionally one might run across the need for this solution. The technique of solving the equations may be of interest to some reliability engineers.

84 METHODS OF RELIABILITY ANALYSIS

R70-15110 ASQC 844

FRETTING FATIGUE FAILURE IN FRICTION GRIP BOLTED JOINTS: RESEARCH NOTES

R. Spiers (University of Leicester, Dept. of Engineering, Leicester, England) and M. S. G. Cullimore (University of Bristol, Dept. of Civil Engineering, Bristol, England) *Journal Mechanical Engineering Science* vol. 10, no. 5 1968 p 434-437 6 refs Sponsored in part by Science Research Council

Fatigue tests on a large number of double cover plate butt joints showed that the cause of failure in the majority of cases was by cracks originating in an annular area of fretting damage around the bolt hole. The nature of the fretting is discussed, and the variation with load amplitude of the size of the annular area is described. Several well defined patterns of fatigue cracking were observed. These are described, and their associated crack origins classified and related to the joint geometry and load levels. Author

Review: This is a short research note and will be informative and interesting reading for engineers who incorporate double-cover-plate butt-joints within their designs (this is a reasonably common type of joint). The document is not, however, a basic reference. Essentially, the authors briefly discuss the results of their research by describing the different patterns of fatigue cracks and the effects of load levels and joint geometry on crack origin. The paper is well referenced to other work so that, if one is truly interested, more details can be obtained.

R70-15118 ASQC 844

Southwest Research Inst., San Antonio, Tex.

NONDESTRUCTIVE EVALUATION OF METAL FATIGUE

F. N. Kusenberger, P. H. Francis, B. E. Leonard, and J. R. Barton Apr. 1969 73 p refs

(Contract AF 49(638)-1502)

(N69-38387; AD-688892; AFOSR-69-1429TR) Avail: CFSTI

Investigations of nondestructive inspection techniques for the early detection and evaluation of fatigue damage in metals have been extended. Photographs of the fatigue evaluation apparatus are shown, and brief descriptions of the ultrasonic, magnetic perturbation, and electric current injection nondestructive techniques are presented. Results obtained using ultrasonic and electric current instrumentations to monitor a stress-cycled Ti-6Al-4V specimen are presented and discussed. Ultrasonic and magnetic perturbation instrumentations were used to monitor many stress-cycled AISI 4340 steel specimens. Magnetic data were accumulated using a very small Hall effect probe and new signal response characteristics were obtained. Reproductions of many ultrasonic and magnetic records are shown; surface photomicrographs showing fatigue microcracks are included. Data are presented that show the lives of AISI 4340 steel specimens can be significantly extended by the local removal of fatigue microcracks. Author (TAB)

Review: Basic research is continuing into the mechanism of fatigue with two main engineering benefits: (1) to make parts less prone to fatigue, and (2) to detect fatigue cracks once they have started. This paper deals largely with the second benefit and gives the results of several experiments for detecting extremely small fatigue cracks and possibly for detecting the discontinuities from which they can start. The first benefit is also attacked along with theoretical development for fatigue crack formation. Virtually all of the paper applies only to the research laboratory so that it is not of direct interest to designers and reliability engineers. However, it will be of considerable value to those who are doing research, both theoretical and experimental, in fatigue, and they should be aware of its contents. It is not necessarily that the work

(especially the theory) is definitive; it is rather that the work is pushing away well at the frontiers.

R70-15123 ASQC 844

Columbia Univ., New York. Dept. of Civil Engineering and Engineering Mechanics.

FATIGUE MECHANISM IN IRON AT ULTRASONIC FREQUENCY

W. A. Wood and W. P. Mason Jun. 1969 15 p refs
(Contract Nonr-266(91))
(N69-39438; AD-690199; TR-66) Avail: CFSTI

A metallographic study compares the fatigue mechanism in low-carbon iron subjected on the one hand to cycles of strain at an ultrasonic frequency of 17,000 Hz and on the other to 1,700 cpm, the relative low order employed in usual engineering tests. It is found that the ultrasonic frequency can produce fatigue cracks at strain amplitudes much smaller than those which up to now have been regarded as safe at low frequency. Further, whereas small amplitudes at low frequency spread abnormal deformation primarily in grain boundaries, those at ultrasonic frequency concentrate it in a relatively few isolated slip bands thereby, it is suggested, heightening their damaging effects. Author (TAB)

Review: This paper is directed largely toward those doing research in fatigue, but it has a message for designers as well. It has been considered in the past that there is a very wide range of frequencies for which the fatigue behavior of iron and steel was relatively insensitive to the frequency, and furthermore, that there was a fatigue limit below which there was negligible fatigue damage. The authors' results show that this is not true at 17 kHZ, a much higher frequency than ordinarily used. There is always the possibility, of course, that there is an unknown source of error in these experiments, and therefore these results should be confirmed as definitely as possible by other completely separate groups who would perhaps even be using different methods. These are not the first tests done at ultrasonic frequencies, certainly, and the work should continue as this range of fatigue is becoming more important.

R70-15130 ASQC 844

FAILURE MECHANISMS IN LARGE SCALE INTEGRATED CIRCUITS

George L. Schnable and Ralph S. Keen, Jr. (Philco-Ford Corp., Microelectronics Div., Blue Bell, Pa.) *Institute of Electrical and Electronics Engineers, Annual Reliability of Physics Symposium, 7th, Washington, D.C., Dec. 2-4, 1968, Paper* 11 p refs *IEEE Transactions on Electron Devices*, vol. ED-16, no. 4 Apr. 1969 p 322-332 41 refs
(Contract AF30(602)-68-C-0133)
(A69-32887)

Study of the factors affecting the reliability of large-scale integrated (LSI) circuits. Particular attention was given to the effect on array reliability of the additional processing steps required to obtain multilevel metalization. The additional significant steps are low temperature deposition of a second dielectric layer on metalized LSI wafers, etching of vias through the second dielectric, and second level metalization. Possible new failure modes in multilevel arrays are (1) shorts or increased leakage through or along deposited second-layer dielectrics, (2) opens or increased series resistance in conductors, and (3) silicon surface effects. Data obtained using test vehicles to evaluate the multilevel metalized array structures are presented. The merits and limitations of the specially designed test vehicles for process development, process control, and reliability tests are discussed. It is concluded that with the proper in-process controls, tests, and screens, LSI arrays will be substantially more reliable per function accomplished than are conventional integrated circuits. Author (I.A.A.)

Review: This paper is a broad survey of the many ways in which large scale integrated (LSI) circuits can fail. The authors attempt to compare LSI reliability problems with those of the more familiar simple integrated circuit. They conclude that LSI is inherently more reliable when time to failure is measured on a per function basis, but do acknowledge that new failure mechanisms arise in extending silicon technology to the multi-level metallization schemes necessary for bipolar LSI. The emphasis of the paper is on those failure mechanisms attributable to multi-level metallization, and the authors describe a large number of potential failure mechanisms (amply supported by a list of over 40 references). Some experimental work is also described in support of the authors' general optimism regarding the future of LSI. The impact of this section of the paper is somewhat reduced by difficulty in following both the details and the general conclusions of the work. The following are examples. (1) None of the photomicrographs of devices or the test structures are keyed to facilitate the distinction between first-level metallization and second-level metallization or dielectric layers. (2) In Figures 9 and 10 particularly, the text explaining the details of the test pattern must be accepted on faith. For example, a lineal capacitor is described as being 0.5 mil wide and 4000 mils long and as having a total area of 1,000 square mils. The ratio of peripheries between a test planar capacitor and the lineal capacitor is given as 16,000 to 1. It is not clear where these numbers came from. (3) Figures 1 and 2, contrasting the appearance of a single metallization DTL gate with that of the same gate with two levels of metallization, do not have the same orientation. In spite of these minor shortcomings, the paper is very worthwhile and contains much interesting and useful information. It is both timely and authoritative.

R70-15131 ASQC 844

ELECTROMIGRATION: A BRIEF SURVEY AND SOME RECENT RESULTS

James R. Black (Motorola, Inc., Semiconductor Products Div., Phoenix, Ariz.) *Institute of Electrical and Electronics Engineers Annual Reliability Physics Symposium, 7th, Washington, D.C., Dec. 2-4, 1968, Paper* 10 p refs *IEEE Transactions on Electron Devices*, vol. ED-16, no. 4 Apr. 1969 p 338-347 21 refs
(Contract F30602-67-C-0166)

Recently, electromigration has been identified as a potential wear-out failure mode for semiconductor devices employing metal film conductors of inadequate cross-sectional area. A brief survey of electromigration indicates that although the effect has been known for several decades, a great deal of the processes involved is still unknown, especially for complex metals and solute ions. Earlier design equations are improved to account for conductor film cross-sectional area as well as film structure, film temperature, and current density. Design curves are presented which permit the construction of high reliability, infinite life aluminum conductors for specific conditions of maximum current and temperature stress expected in use. It is also shown that positive gradients, in terms of electron flow, of temperature, current density, or ion diffusion coefficient foreshorten conductor life because they present regions where vacancies condense to form voids. Author

Review: This electromigration paper is substantially the same as that published by the same author in the Proceedings of the

IEEE, vol. 57, Sep. 69, pp. 1587-1594 (see R70-15045). Several additional plots are given in the present paper which do not appear in the Proceedings paper. These additional plots include design curves showing the predicted mean times-to-failure for variously formed aluminum conductors (cold substrate deposited, heated substrate and heated substrate plus SiO_2 overcoat) as a function of temperature and current density. The two papers, however, carry the same message and use substantially the same data and illustrations to tell the same story. The comments made in R70-15045 apply equally well to this paper even though the Proceedings paper was published several months later. Other papers in this issue of the IEEE Transactions on Electron Devices also discuss electromigration in aluminum films as well as other related subjects.

R70-15132 ASQC 844; 775

THE APPLICATION OF THE SCANNING ELECTRON MICROSCOPE TO THE DEVELOPMENT OF HIGH RELIABILITY SEMICONDUCTOR PRODUCTS

Ronald H. Cox, Delbert L. Crosthwait, Jr., and Robert D. Dobrott (Texas Instruments, Inc., Dallas, Tex.) *Institute of Electrical and Electronics Engineers, Annual Reliability of Physics Symposium, 7th, Washington, D.C., Dec. 2-4, 1968, Paper* 5 p refs *IEEE Transactions on Electron Devices,* vol. ED-16, no. 4 Apr. 1969 p 376-380 4 refs

(A69-32892)

Examples illustrating the wide range of applicability of the scanning electron microscope to the processing of high-reliability semiconductor products. The three areas selected are devitrifying solder glass seals for hermetic packages, voltage contrast examination of biased integrated circuits, and metallization corrosion problems encountered in processing technology. The scanning electron microscope gave useful information quickly, and, in some cases, it gave answers that other methods were unable to supply

Author (IAA)

Review: This paper is related to physics-of-failure; that is, close examination of the details of construction and appearance of a part can give a clue as to its reliability. The photographs are reproduced very well although it is not always easy to find the defects mentioned by the authors (at least for the non-specialist). The paper will be a big help to those who are only vaguely familiar with the potential of the scanning electron microscope since this paper quite graphically shows the fidelity with which the instrument can portray the surface region. The pictures and text are arranged for a good tutorial presentation, all of which improves the value of the paper. For those who are new to this field, it should be pointed out that the quality of the pictures does depend somewhat on specimen preparation and the abilities of the microscopist and that, at magnifications of 1000 (most of the pictures are that magnification), it may require a good deal of searching to find the region which has the interesting informative features.

R70-15138 ASQC 844

Aeronautical Research Labs., Melbourne (Australia).

A PROPOSAL FOR A LIFE METER FOR TURBINE BLADES IN AERO ENGINES

F. J. P. Wood Apr. 1969 19 p refs

(N70-10222; ARL/ME-307) Avail: CFSTI

The effects of temperature and stress on aero engine turbine blade life are discussed. A modification to an existing instrument is proposed, to enable the generation of a counting rate proportional to a function of jet pipe temperature and engine speed that should represent approximately the rate of blade creep. The count of such an instrument should give a measure that could usefully be correlated with blade deterioration in service, under conditions of varying stress and temperature, and hence the instrument could be used as a life meter. The principle is illustrated using the example of the Avon engine.

Author

Review: The author presents an interesting analysis and one which may spur further research or be useful in itself. The engineering impetus for the analysis is worthwhile, namely, to find a method of empirically measuring the cumulative damage of the turbine blades. The analysis considers creep only, and presumes a linear cumulation of creep damage at a rate proportional to the reciprocal of the creep rupture life at each temperature and stress. In determining a safe amount of damage, one will have to take into consideration the quite wide scatter in creep-rupture life at any particular set of conditions. (The author has privately stated that the scatter is dealt with in his Note ARL/ME 309, Oct 69. He also mentioned the work of R. Hohenberg in this area published in ASME Publication 69-GT69.) Even if a blade life gage is not developed based on this analysis, at the very least, the analysis should spur others to find an even better solution.

R70-15141 ASQC 844

TOTAL SERVICE LIFE OF A METAL UNDER FLUCTUATING LOADING

G. N. Geminov *Russian Metallurgy,* no. 3 1968 p 93-98 8 refs

Some general principles which are valid under conditions of prolonged loading are discussed. Only secondary loadings are considered. In estimating the effects of relative strengthening or weakening of metal at a given stress level, comparison and reference to the primary curve are made and residual service life is determined.

Author

Review: There is a constant search for ways of predicting the fatigue life of metallic parts whenever cumulative damage is involved and especially when there are competing failure mechanisms. The principle expounded in the early part of this paper, while true, is like "belling the cat." The author states that after each load interval, one needs to derive a new service life curve for the changed metal. While this statement is almost a truism, in practice it is the hopelessness of the cause that makes people look for other ways of predicting service life. The author does make some good points about the relative shapes of the secondary and primary curves and what one can learn from them about the metal. These points rather than the actual prediction of life are the main value of the paper.

R70-15142 ASQC 844

OPERATING PROBLEMS WITH HIGH SPEED TURBOMACHINERY CAUSES AND CORRECTION

J. S. Sohre (The Terry Steam Turbine Co., Hartford, Conn.) *ASME Petroleum Mechanical Engineering Conference, Dallas, Sep. 23, 1968, Paper* 22 p refs

An attempt is made to coordinate the causes and effects of vibration problems, as experienced during operation of highspeed turbomachinery, hoping to reduce the gap between theory and practical application. The data presented in tabular form, coordinating almost 6000 items to provide easy reference for the troubleshooter in the field, form a basis for reliability analysis. Author

Review: This is a very practical paper. Its main purpose is to provide a useful, easy reference for troubleshooters in the field. It provides for rotating machinery what reliability engineers often call a failure modes and effects analysis. As such, it can be quite useful. Another group which can benefit from the paper, and which was not explicitly mentioned by the author, is designers. The checklists for the field engineer are just as valuable for the designer, assuming that he does not have some more comprehensive ones of his own. This is especially true with people who are being called upon to perform outside the field of their specialty. Checklists such as this one are extremely valuable for them. The paper is short and easy to read; becoming familiar with the charts themselves will take a little time, but it will be worthwhile.

R70-15145 ASQC 844
FATIGUE OF LARGE COMPONENTS UNDER PULSATING COMPRESSIVE STRESSES
B. A. Morozov *Russian Engineering Journal,* vol. 49, no. 2 1969 p 17-19 6 refs

By taking into account the characteristics of the fatigue strength in compression, one can obtain a considerable economy of metal when large cast components are cyclically loaded with average stress compressive. The load-carrying capacity of the base components of large machines (bedplates, supports, cross-members, girders), which are at the limit of fabricability, can be increased considerably without changing metal content, by prestressing to take the working cycle of stresses into the compression zone. Author

Review: This short note presents the results of tests which were designed to verify that compressive fatigue strengths are greater than tensile fatigue strength. Failure is determined by crack propagation rather than crack initiation (there is no discussion of the time to crack initiation). The results did confirm the hypothesis, and the rather conventional explanation is that the cracks do not propagate as readily under the compressive stresses as they do under tensile stresses. While the actual data will be of little value to American designers, the principles involved are worth being verified occasionally, and those doing research in the field ought to appreciate their having been verified. While few people are surprised at the answer, every once in a while such verification does prove surprises, since people occasionally do believe in incorrect theories.

R70-15148 ASQC 844
LSI RELIABILITY ASSESSMENT AND PREDICTION
H. A. Lauffenburger and T. R. Myers (IIT. Research Institute, Chicago, Ill.) *In: Proceedings of the 1970 Annual Symposium on Reliability Los Angeles, Feb 3-5, 1970* Symposium sponsored by the Institute of Electrical and Electronics Engineers, Institute of Environmental Sciences, American Society for Nondestructive Testing, and American Society for Quality Control New York IEEE, Inc. 1970 p 364-380 23 refs

In Large Scale Integration (LSI), greater emphasis must be given to designing reliability into the product from the early system concept stage and continuing on through deployment. The LSI component supplier selection, design reviews, and in-process inspections play increasingly important roles in establishing confidence in product acceptability. Screening and burn-in appear to still be economical means for detecting discrepant components. Quality assurance and life tests concentrate on specially designed test elements to determine design and process capability, failure mechanism kinetics, and adequacy of production controls. Reliability levels are estimated with data from these elemental tests using appropriately structured mathematical models. It is noted that LSI has provided the reliability engineering professing an opportunity to make a greater impact on electronic system reliability. Author

Review: As integrated circuits become complex and many functions are performed on a single chip, with only the input-output terminals being available, users are finding that their reliability analysis is becoming more like that of mechanical components which are similarly complex. The authors point out that an LSI component is a system rather than just a component part. But all component parts are systems to the people who make them; they only appear to be simple component parts to some of the people who use them later and even then only after the maker has been able to produce an extremely uniform device. The discussions of LSI failure modes and mechanisms, and other reliability physics aspects of the paper, are quite good and certainly can serve as useful checklists for users. The parts of the paper which attempt to deal with the relationships between the supplier and the buyer are on less firm ground. The viewpoint concerning the relationship between supplier and buyer is worthy of serious consideration; however, life is rarely as simple as can be inferred from the discussion. People have trouble buying simple components like resistors and capacitors. When one gets the engineering and purchasing departments in one company working with the sales, engineering, and production departments of another company, there is a great deal of conflict of interest, communication problems, and product quality claims which cannot be wholly supported. These relationships also depend, for example, on whether it is a buyer's or seller's market. Thus, making the required cooperation work well will require more effort and sophistication from all parties than has often been necessary in the past. The problems of inspection are discussed, but 100% inspection of many things is extremely difficult especially if it involves the geometry of something on the chip rather than terminal measurements. Work is being done with various optical and analytic techniques to be able to show only deviations from the proper pattern, but these are nowhere near the production use stage. The use of test chips has a lot of potential, but this potential should not be confused with achievement in practice. Anytime there is a great deal of variability in a characteristic and only a small number are tested, the statistical power of the test is a matter of great concern and is often overlooked. When using field data rather than test data, one can perhaps get more of them, but it takes much work in order to get reliable field data. It is not easy to see what benefits are achieved by considering the population as made up of two subpopulations, one of which is excellent and the other of which contains the difficulties, unless there is some easy way of sorting the two. Such a combination could produce essentially the kind of behavior that is observed now. But that approach has appeal in some areas and is considered a useful way of looking at the situation. The paper is worth reading; the best parts of it give insight into the physical characteristics of LSI and the difficulties to be expected therein. The balance of the paper shows the considerations that will have to be faced sooner or later by users and suppliers. Thus, the paper will be helpful to managers, and reliability and design engineers who expect to become involved with large scale integration.

R70-15149 ASQC 844
FAILURE ANALYSIS FOR IC PROCESS IMPROVEMENT
J. E. Lawrence and M. S. Khidr (Fairchild Semiconductor Corp., R-OA, Mountain View, Calif.) *In: Proceedings of the 1970 Annual Symposium on Reliability, Los Angeles, Feb. 3-5, 1970* Symposium sponsored by the Institute of Electrical and Electronics Engineers, Institute of Environmental Sciences, American Society for Nondestructive Testing, and American Society for Quality Control New York IEEE, Inc. 1970 p 381-385 8 refs

It is concluded that several basic steps such as failure mode identification, failure simulation, process development, monitor development, stress test development, failure rate evaluation, and a failure mechanism study should be included in third generation reliability. A generalized procedure for a third generation reliability approach to integrated circuit product quality improvement is presented. A specific third generation reliability program is reviewed in more detail to illustrate the dependence of product improvement on failure analysis techniques through each phase of the program. Author

Review: The paper very briefly describes what is termed the third generation approach to process improvement: isolating a failure mode, developing and understanding it, and then changing the process to eliminate it (we hope). The balance and largest part of the paper is devoted to an application of this procedure. The early part of the discussion will be of help to reliability engineers generally, but the balance of the paper will be of value largely to those interested in the detailed behavior of integrated circuits as explained below. Experienced readers will recognize the presentation as one of the successful applications of the method, but will realize that undoubtedly one can expect some unsuccessful applications also. Documentation of process problems–particularly those associated with contamination–are extremely rare in the literature. The application (mentioned above) is an excellent description of such a rarity. The reason for this scarceness in the literature is not that their occurrence in practice is infrequent but is that their isolation and solution are elusive and their documentation and description is time-consuming and often unflattering. All too often, problems disappear before they are recognized and solved, only to reappear at a later time. The example describes and illustrates the deleterious effect of contaminating organics upon the aluminum-silicon contact common to integrated circuits. The well-illustrated failures have the following two major modes: (1) a high resistance or open aluminum-to-silicon-contact which shows no visible degradation even under subsequent sintering in excess of 500°C, (2) a discolored deeply pitted region in the aluminum following sintering, suggesting that considerable silicon has been dissolved by the aluminum in a small localized region. Uniform alloying was being prevented by a thin surface film deposited during evaporation by organic contaminants, as demonstrated by: (1) changing to a different evaporator, and (2) contaminating a good evaporator with various oils. The problem disappeared in case 1 and reappeared in case 2. The original cause of the evaporator problem and the corrective action are not spelled out other than to imply that removal of the original source of contamination solved the problem. The text does not illustrate the appearance of the ideal, high-quality sintered aluminum-silicon contact with which these failures could be compared. The abstract accompanying the paper discusses this specific problem as an illustration of "third generation reliability." The presentation of the term "third generation reliability" could lead the reader to expect it to be novel. It is not. The authors define it as "joining failure analysis to product quality improvement," which is what reliability physicists have been trying to do all along. The language and description are clear; the reader can follow the action easily. The captions of Figures 1 and 3 are interchanged, but this causes no serious difficulty.

R70-15150 ASQC 844
CHARACTERISTIC TRAITS OF SEMICONDUCTORS FAILURES
W. J. Lytle and Owen J. McAteer (Westinghouse Defense and Space Center, Aerospace Div., Baltimore, Md.) *In: Proceedings of the 1970 Annual Symposium on Reliability, Los Angeles, Feb. 3-5, 1970* Symposium sponsored by the Institute of Electrical and Electronics Engineers, Institute of Environmental Sciences, American Society for Nondestructive Testing, and American Society for Quality Control New York IEEE, Inc. 1970 p 386-393 4 refs

The relative importance of visual microscopic data as it pertains to recognizing the characteristic traits of a semiconductor failures are discussed. This visual data can be a tremendous aid to the analyst in identifying the cause of semiconductor failure due to external influence. Residual damage observed on a microcircuit surface is often the result of temperature excursions localized at the chip surface. Temperature excursions that occur with certain types of damage to microcircuits are discussed in terms of voltage, current, and time, and are thereby related to the nature of the external abuse. Some of the characteristic traits which have been identified to date are presented. Case histories which describe the usefulness of these clues when applied during system failure analysis are related. Author

Review: This paper is designed for the failure analyst of semiconductor devices. It limits itself exclusively to what can be observed (and consequently inferred) from microscopic examination (both high and low magnifications). The authors contend that a great deal more can be learned from this examination than is often credited. Their pictures are clear, and the development is convincingly presented. Obviously, a great deal of experience is necessary to implement this procedure fully. Even though there may be some analysts who would dispute the comprehensiveness of the claims made in this paper, all analysts will benefit from the experience of these people and from trying to improve their own skills with it. The interchange of this kind of information is especially helpful because there are always newcomers to the field who must be educated and because even the oldtimers need to be refreshed occasionally.

R70-15163 ASQC 844
STRESS CORROSION CRACKING CHARACTERIZATION PROCEDURES AND INTERPRETATIONS TO FAILURE-SAFE USE OF TITANIUM ALLOYS
R. W. Judy, Jr. and R. J. Goode (Naval Research Lab., Metallurgy Div., Strength of Metals Branch, Washington, D.C.) *American Society of Mechanical Engineers, Metals Engineering and Pressure Vessels and Piping Conference, Washington, D.C., Mar. 31-Apr. 2, 1969, Paper* 6 p refs *ASME Transactions, Series D, Journal of Basic Engineering,* vol. 91, no. 4 Dec. 1969 p 614-617 8 refs Navy-ARPA supported research
(A70-21456; ASME-Paper-69-MET-7)

Ratio analysis diagram (RAD) interpretive procedures have been evolved recently to provide generalized engineering solutions for fracture toughness assessments of structural titanium alloys. Failure-safe design also requires consideration of possible subcritical crack propagation (slow fracture) due to stress-corrosion cracking (SCC). Procedures for incorporation of SCC characterizations into the RAD system have now been developed. These procedures serve the dual purpose of providing simplified interpretations of critical flaw size-stress instability conditions by consideration of resistance of the material to both fast fracture and SCC. The failure conditions are expressed in terms of ratios which provide an index of the general level of critical flaw sizes. Author (IAA)

Review: This paper is a good illustration of the fact that advances being made in one field can aid those in another. Even though these pressure vessels are intended for submarine service, the same principles obviously apply to those used in aerospace applications. Fracture mechanics is largely being used in the more esoteric design fields but will undoubtedly spread to the others as more and more engineers learn about it and find they can apply it. This is not a tutorial paper, and anyone not previously familiar with applying this form of fracture mechanics will need help other than this paper. It does do a good job of explaining the additional considerations of stress-corrosion cracking. Although the applications are to titanium alloys, there is no reason to expect that similar considerations would not hold for other alloys. Design and reliability engineers who are not familiar with this kind of analysis would do well to look up some of the references mentioned in this report and elsewhere so that they can become familiar with it. As factors of safety become smaller and more exact design methods are used, more failure mechanisms appear and they must be both investigated in research and considered in applications. Even though the data in this paper apply only to salt water, they could be extended to other corrosive environments.

R70-15164 ASQC 844
FATIGUE RESISTANT FASTENER
F. E. Smode and H. Wittmeyer (Huck Manufacturing Co., Detroit, Mich.) *ASME Design Engineering Conference and Exhibit, New York, May 5-8, 1969, Paper* 7 p refs *In: Proceedings of Aircraft Structures and Materials Application; National Sample Technical Conference, Vol. 1, Seattle, Sep. 9-11, 1969* Conference sponsored by Society of Aerospace Material and Process Engineers North Hollywood, Calif. Western Periodicals Co. 1969 p 261-269 17 refs
(A69-43438; ASME-PAPER-69-DE-42)

Brief historical summary of fatigue as related to bolted joints. The influence of various types of fasteners on the fatigue life of joints is discussed. The experimental program showed the effect of clamping force on fatigue life using two types of joints. Butt joints and lap joints containing high clamping force fasteners were constant amplitude fatigue tested, and the results were compared with data on joints containing other mechanical fastenings. The comparison of these data with earlier results shows that high clamping force has a beneficial effect on fatigue life of joints. Author (IAA)

Review: This is a tutorial paper combined with a description of a proprietary fastener. The summary of fatigue as related to bolted joints is good and probably understandable to the readership to whom it is directed. The balance of the paper shows the disadvantage of using torque as a measure of fastening force and shows how the proprietary fastener achieves a good clamping force without depending on a torque measurement. Several fatigue curves are shown to illustrate the superiority of this new fastener. It is not clear whether the comparison curves were made with the same materials on the same machines as the proprietary fastener tests. If not, there is some danger in taking such curves from the literature and comparing them with one's own. There are many important items which should be considered in a fastened joint in addition to its fatigue life, such as cost, ease of manufacture and ease of assembly.

R70-15165 ASQC 844
CORROSION FATIGUE CRACK PROPAGATION STUDIES OF SOME NEW HIGH STRENGTH STRUCTURAL STEELS
T. W. Crooker and E. A. Lange (Naval Research Lab., Metallurgy Div., Strength of Metals Branch, Structural Metals Criteria Sect., Washington, D.C.) *American Society of Mechanical Engineers, Metals Engineering and Pressure Vessels and Piping Conference, Washington, D.C., Mar. 31-Apr. 2, 1969, Paper* 8 p refs *ASME Transactions, Series D, Journal of Basic Engineering,* vol. 91, no. 4 Dec. 1969 p 570-574 26 refs Navy supported research
(A70-21452; ASME-Paper-69-MET-5)

Fatigue crack propagation studies were conducted on three new high-strength structural steels: 9Ni-4Co-0.20C quenched-and-tempered, 10Ni-2Cr-1MO-8CO dual-strengthened, and 13Cr-8Ni-2Mo precipitation-hardened stainless. The yield strengths of these steels ranged from 176 to 193 ksi. Notched cantilever-bend specimens of each steel were cycled zero-to-tension in two environments, room air and 3.5 percent NaCl salt water. Fatigue crack growth rates were measured experimentally and correlated with the crack tip stress intensity factor range. The results indicate that these new steels possess greater resistance to fatigue crack propagation and less sensitivity to environment than previously studied steels of comparable strength. Author (IAA)

Review: This report will be of value largely to metallurgists who are doing research in this field, but many of the concepts and explanations introduced here ought to be brought to the attention of designers. The high-strength structural steels are popular in some aerospace structures as a weight-saving feature. It has not always been clear to designers that in many cases they were sacrificing other kinds of strength to get the improved tensile strength. This paper provides a worthwhile service in showing how the high-strength steels have been improved and indicating (by implication) the characteristics designers should be considering. Both the technique for evaluating these new steels and the results themselves are important. The organization and language of the paper are such that the paper is directed toward those with experience in this field. It will not be very suitable for tutorial purposes otherwise. There are many references, both to support the authors' points and for further reading.

R70-15168 ASQC 844; 775
THE APPLICABILITY OF A FRACTURE MECHANICS NON-DESTRUCTIVE TESTING DESIGN CRITERION FOR AEROSPACE STRUCTURES
P. F. Packman (Vanderbilt University, Div. of Materials Science, Nashville, Tenn.) H. S. Pearson, J. S. Owens (Lockheed-Georgia Co. Marietta, Ga.) G. Young (USAF, Materials Lab., Wright-Patterson AFB, Ohio) (*Western Metal Congress, Los Angeles, Mar. 10, 1969, Paper* 11 p refs) *ASM Metals Engineering Quarterly,* vol. 9, no. 3 Aug. 1969 p 52-62 13 refs
(Contract AF F33615-67-G-1150;DAAD05-69-C-0043)
(A69-38656)

Experimental verification of a design procedure for aerospace structures using the concepts of linear elastic fracture mechanics and nondestructive inspection. The design procedure utilizes the value of the critical plane strain intensity factor and the size of the critical flaw as determined by nondestructive testing to predict the failure load of a simple test specimen. The deviations between the failure compared as a function of the actual crack size measured on the failed specimen. The deviation between the actual failure load and a failure load prediction using MIL-Handbook 5 was also calculated. The results for 7075-T-6511 aluminum and 4330V modified steel are summarized, and show that the use of a FM-NDT design criterion for aerospace structures has potential application

with additional development of fracture mechanics and enhancement of crack definition by NDT. IAA

Review: This is a very good paper. Its topic is of importance to reliability and design engineers; fracture mechanics is becoming increasingly active. The explanations of the conventional probabilistic design and of the fracture mechanics designs are good and are easy to follow. (When very many probabilities are combined at a particular confidence level, the overall confidence and probability of success need to be modified.) Proponents of design by fracture mechanics are finding that, as with many other theories, getting accurate data for design is more difficult than writing the equations. The paper is extremely worthwhile since it tests a very practical method of getting data to use in design against the actual performance. The authors' explanations are good and they can be understood by those without an extensive background in fracture mechanics or in probability. References are given for those who wish to dig deeper. Furthermore, the authors have not been blindly overenthusiastic about their method; they seem to have evaluated the data very fairly, given its advantages vs. its disadvantages, and very usefully pointed out the areas for further research. In short, this seems to be a model for others to follow in preparing papers for publication on their good ideas; not to mention the fact that the material is very applicable for aerospace reliability.

85 DEMONSTRATION/MEASUREMENT

R70-15128 ASQC 851; 612
Naval Postgraduate School, Monterey, Calif.
ON FAULT IDENTIFICATION OF LINEAR NETWORKS
James Richard Dyer (M.S. Thesis) Jun. 1969 60 p refs
(N70-10706; AD-692445) Avail: CFSTI

A study has been made on the possibility of identifying faulty components of a network by making tests only on external points of that network. The conclusion is made that this is possible, and that a practical method of doing this can be developed from the computer program presented as a result of this investigation. The method used is to select the voltage transfer functions of a network as the quantities on which the tests will be made. The poles and zeros of these functions are used to select a set of test frequencies. From the measurements made at these frequencies, a set of signatures is available which allow the faulty components to be identified. Author (TAB)

Review: The purpose of this thesis is to demonstrate the feasibility of a proposed method of fault detection and diagnosis in linear continuous networks. The investigation was limited to two-port, passive networks. Fault signatures were developed by applying a set of test frequencies at the circuit input and observing the corresponding value of the transfer function. The frequencies employed for checking purposes are corner frequencies of the first and higher order factors of the voltage transfer function as well as additional arbitrary test frequencies. The following are weak areas in the thesis. (1) There is little discussion of previous developments in this field. The feasibility of the proposed method of fault diagnosis was shown by Seshu and Waxman [1] (the author's reference 1), and the author has duplicated much of their work. (2) The method of selecting test frequencies needs to be investigated in greater detail. The author admits that it may be possible to find a set of fewer test frequencies which yield as good or better results for the circuit configurations he has considered. (3) Very little is given regarding the author's results except that they have been "very encouraging." For more complete information, interested readers can consult the paper by Seshu and Waxman [1] and the paper by Maenpaa, et al. covered by R69-14589.

Reference: [1] Seshu, S. and R. Waxman, "Fault Isolation in Conventional Linear Systems: A Feasibility Study," IEEE Transactions on Reliability, vol. R-15, no. 1, May 1966.

R70-15133 ASQC 851; 612
Naval Postgraduate School, Monterey, Calif.
A TOPOLOGICAL APPROACH TO FAULT ISOLATION
James Dewey Courville (M.S. Thesis) Jun. 1969 164 p refs
(N70-10830; AD-692456) Avail: CFSTI

A method is developed for determining by simple external measurements faulty components of passive networks without mutual inductances. A program has been written using topological relationships to calculate the necessary fault isolation reference data. Computation time and storage requirements have been maintained at a minimum. Author (TAB)

Review: This well-written thesis is concerned mainly with the automation of a testing procedure for locating faults in passive networks (no mutual inductance allowed). Faults are isolated by applying to the network a set of test frequencies and observing the corresponding values of the voltage transfer function. In order to diagnose faults, it is required that the value of the transfer function be calculated as the network components are varied about their nominal values. A deviation between the response of a faulty network and the network's normally expected response permits the identification of a fault. Of major concern in this thesis is the use of topological formulas for the rapid determination of the voltage transfer ratios. These formulas result in an efficient means of automatic fault diagnosis. A computer program for fault isolation (written in FORTRAN IV) is included as well as a detailed discussion of how to use the program. Two illustrative examples of fault isolation data resulting from the author's study are given. The major weakness is the lack of a discussion of previous developments in this field. This study represents a step in the right direction toward automatic fault isolation in continuous systems and should be of much interest to engineers involved in this area of research.

86 FIELD/CONSUMER ACTIVITY

No abstracts in this issue.

87 MAINTAINABILITY

R70-15126 ASQC 872; 838
Institute of Electrical and Electronics Engineers, New York. Computer Group Repository.
SELF REPAIRING DIGITAL SYSTEMS USING FEW SPARES
Glenn R. Linsenmayer [1969] 29 p refs
(R-69-155)

A method is discussed for providing automatic self-repair capability in electronic equipment, particularly digital equipment. The emphasis is placed upon achieving useful reliability improvement for small cost or weight increase, rather than on obtaining maximum reliability regardless of cost. The approach considered involves partitioning the equipment into similar or identical elements having relatively few inputs and outputs per element, and providing a single spare together with associated switching logic to serve as a replacement for any single failed element. This technique is compatible with LSI technology, and offers significant advantages over methods such as duplication and triplication whenever cost or weight are important, for example, in avionics, earth satellites, and interplanetary probes. Self-repair is obtained without degradation in operating capability. General results are described including consideration of imperfect testing and switching circuits. Specific applications to a digital filter and to a general purpose computer are discussed. Author

Review: This is an interesting paper which further explores the means by which redundancy/repair can be effectively introduced into electronic systems. The dividing line between redundancy and automatic maintenance is never clear and the distinction may not be worth making. This paper represents a worthwhile exploration of this field; it makes and analyzes some good suggestions. Many of the conclusions depend very heavily on what assumption is made about failure rate versus complexity (presumably the failure rate decreases as the complexity decreases). With integrated circuits, this relationship is not clearcut and will probably continue to change as new developments and applications occur with larger-scale integration. Nevertheless, this is a worthwhile technique for reliability engineers and designers to investigate.

R70-15155 ASQC 872

SYSTEMS MAINTAINABILITY MODELING

Thaddeus L. Regulinski (Air Force Institute of Technology, Wright-Patterson Air Force Base, Ohio) *In: Proceedings of the 1970 Annual Symposium on Reliability, Los Angeles, Feb. 3-5, 1970* Symposium sponsored by the Institute of Electrical and Electronics Engineers, Institute of Environmental Sciences, American Society for Nondestructive Testing, and American Society for Quality Control New York IEEE, Inc. 1970 p 449-457 23 refs

A system may be defined as a device, procedure, or a scheme which behaves according to some predetermined structure. To be able to study quantitatively the behavior of a given system, it is necessary to formulate a mathematical analog. This formulation constitutes the essence of modeling. When the study is directed at a system governed by independent variables the formulation constitutes system deterministic modeling. When the study is directed at a system governed by functions of some random variables, the formulation constitutes system stochastic modeling. Specifically, stochastic modeling of the system parameter maintainability is discussed. Author

Review: The essence of this paper is a handbook-like presentation of the quantitative characteristics of eight density functions. The density functions covered include those typically used in reliability-maintainability analysis as well as several others such as the logistic distribution. These density functions are as potentially useful for failure-time modeling as for repair time modeling. The real problem is to select a density function for maintainability or related problems which represents the actual situation realistically. This paper will be useful as a handy reference for the equations which it contains. It is always a good idea to check such equations against other sources, as this type of material is susceptible to misprints.

R70-15159 ASQC 872; 824

Genge Industries, Inc., Sherman Oaks, Calif. Scientific and Consulting Div.

PREDICTION-ALLOCATION-MATHEMATICAL MODELING MAINTAINABILITY (M) QUANTITATIVE DESIGN PARAMETERS

George W. Dauncey [1969] 21 p refs
(N69-36916; AD-688723) Avail: CFSTI

This presentation is a challenging Maintainability (M)Engineering discipline technique which provides a dynamic and simplified method for management visibility of the maintenance action times and frequency of maintenance tasks involved in the establishment of the M quantitative constraints required to be designed into system equipments. The prediction technique is used to develop the M design parameters of means and maximum times and the standard deviation of maintenance times requirements and allocations to be designed into equipments to satisfy the operational mission downtime constraints imposed or desired. The effectivity of the predictions of these basic parameters is shown to be the basic requirements for the establishment of the Integrated Logistic Support (ILS) planning and its associated minimization of the life cycle support costs. The visibility provides a basis for evaluation of the M/ILS demonstrations and the design changes effects on the M constraint requirements. Author (TAB)

Review: This report treats the problem of obtaining estimates of system maintainability parameters (e.g., mean repair time, standard deviation of repair time, and maximum repair time) using repair time and frequency of failure data on components. Reading the report, especially the first part, is very laborious due mainly to the wordiness. However, the procedures are adequately described even to the point of being "cookbookish" in places, and appear to be technically sound. Contrary to impressions easily gained early in the report, the report does not treat the total integrated Logistics Support and life-cycle-coasting problem other than by briefly discussing how the maintainability parameters might be used in such an analysis. Treatment of this larger-scope problem would require many other inputs pertaining to costs, cost modeling, logistics posture, and operational deployment. (In Equations (1) through (4), λi should be $\lambda' i$.)

R70-15166 ASQC 871; 612

COMPUTERS IN MAINTENANCE CONTROL

W. O. Nicholson (Northrop Corp., Northrop Nortronics, Palos Verdes Estates, Calif.) *International Aerospace Exposition, Montreal, Canada, Nov. 27, 1968, Paper* 5 p *Canadian Aeronautics and Space Journal*, vol. 15, no. 6 June 1969 p 225-229 (A69-33649)

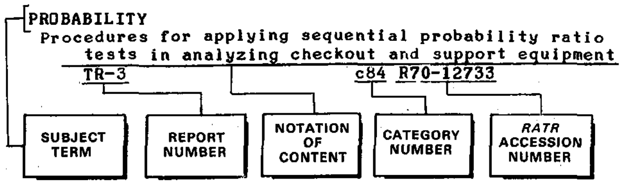
Life cycle maintenance costs of today's sophisticated systems are often many times the acquisition costs. This has caused industry and government both to consider not only initial acquisition costs but also life cycle maintenance costs during major procurements. With more costly and complex equipment in store, maintenance costs will grow still larger unless the computer, which has successfully reduced costs in design and development, manufacture, and operation areas, is also applied to control the maintenance phase of the aerospace industry. Examples of military and airline maintenance expenditures are given, and several on-line and off-line test systems are described. Author (IAA)

Review: The information in the introduction to this paper on the high relative cost of maintenance is familiar to most reliability engineers and is an area which they have been trying to control for some time. The balance of the paper deals largely with automatic checkout/test for maintenance. The paper seems to imply that obviously automatic checkout/test will be cheaper than performing those functions manually. While that is the designer's hope, the hypothesis needs to be proved in terms of the whole system to see whether total costs are going to be lower. It has obviously turned out in many cases that costs are lower with automatic checkout/test. In the author's examples of nominally failed components' being found satisfactory when tested in the shop, it is implied that this automatic checkout will take place *in situ* rather than after removal. Otherwise, it would not help with the problem of unfounded complaints. There is another reason for unfounded complaints: it is generally more satisfactory from an operator's point of view to complain about the hardware than to admit a mistake of his own. The paper is worthwhile for those not acquainted with the author's message and also for those who would like a summary of the automatic test and checkout equipment being developed (largely by the armed forces).

SUBJECT INDEX

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS VOLUME 10 NUMBER 7

Typical Subject Index Listing



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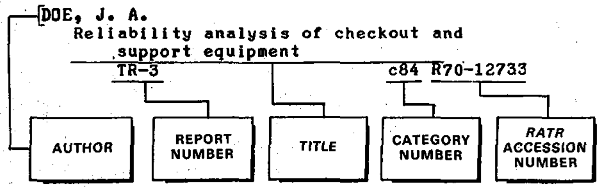
PERSONAL AUTHOR INDEX

Typical Personal Author Index Listing



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REPORT AND CODE INDEX

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Reliability Abstracts and Technical Reviews

AUGUST 1970

Volume 10
Number 8

R70-15169—R70-15216

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The second section of *RATR* contains four indexes: The Subject Index is to assist in scanning or searching the literature on specific topics. The Personal Author Index identifies the publications of specific authors. The Report and Code Index is a listing of the report numbers of items abstracted and reviewed in the journal; this index also includes a listing of the ASQC codes for identifying the *RATR* accession numbers of the items to which the codes have been assigned. The Accession Number Index identifies the categories in which the abstract-reviews appear in the journal. Cumulative indexes are published annually.

EXAMPLES OF CITATIONS IN *RATR*

ASQC CODES

***RATR* ACCESSION NUMBER** → R70-12733 ASQC 844; 413 ← **ASQC CODES**

General Equipment Company, Banville, Calif. ← **CORPORATE SOURCE**

TITLE → **RELIABILITY ANALYSIS OF CHECKOUT AND SUPPORT EQUIPMENT**

AUTHOR → John A. Doe 23 Sep. 1969 27 p refs ← **PUBLICATION DATE**

CONTRACT OR GRANT → (Contract NAS15-13411)

REPORT NUMBER → (AD-629305; N69-15098; TR-3) Avail: CFSTI ← ***TAB* AND *STAR* ACCESSION NUMBERS**; **SALES AGENCY**

***RATR* ACCESSION NUMBER** → R70-12739 ASQC 814 ← **ASQC CODE**

TITLE → **SEMICONDUCTOR RELIABILITY**

Joseph A. Smith (Eastern University, Arlington, Penn.) ← **AUTHOR AND AFFILIATION**

JOURNAL REFERENCE → *Electric Journal,* vol. 8, Apr. 1969, p 478–492.

(A69-12569) ← ***IAA* ACCESSION NUMBER**

***RATR* ACCESSION NUMBER** → R70-12765 ASQC 773; 221; 823 ← **ASQC CODES**

TITLE → **TESTS OF SYSTEMS WITH SOME DEPENDENT FAILURES**

Joseph A. Smith (Eastern University, Arlington, Penn.) and B. James White (General Equipment Company, Banville, Calif.) ← **AUTHORS AND AFFILIATIONS**

CONFERENCE OR SYMPOSIUM REFERENCE → *Association of Reliability Engineering, Failure Rate Conference, Olney, Tex., Mar. 13–17, 1969,* 8 p. Available from Assoc. of Reliability Eng., New York: $1.00 ← **AVAILABILITY AND PRICE**

***IAA* ACCESSION NUMBER** → (A69-12407)

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Reliability Abstracts and Technical Reviews

A Monthly Publication

of the National Aeronautics and Space Administration

August 1970

80 RELIABILITY

No abstracts in this issue

81 MANAGEMENT OF RELIABILITY FUNCTION

R70-15170 ASQC 813
INTERPLANETARY PIONEER SUCCESS STORY
Thomas M. Lough (TRW Systems, Redondo Beach, Calif.) John Mulkern (NASA/ARC, Moffett Field, Calif.) and Bernard Roseman WINCON 70, IEEE, *Los Angeles, Feb. 1970, Paper* 26 p Sponsored by NASA

A short summary is given of: history and objectives of the Pioneer A-E program; spacecraft description and program requirements; science and orbital positions of spacecraft; results of the program; significant aspects of the reliability program; and causes of major problems and where detected. The conclusion discusses the Pioneer F-G mission and describes where additional reliability will be placed. Author

Review: This paper provides a case history summary of another successful reliability program. It is well-written, easy to read, and does a good job of highlighting the special features of the program which appear to be important to its success. It will be worthwhile reading for reliability and program managers who wish to compare their program with others. As in other programs involving incentive fees, it is difficult to determine precisely how much of the success can be attributed to the incentive provision. (See also the paper by Lindstrom and reviewed in this issue of *RATR* for reference to another program involving incentive fees.) The authors are commended for reporting the faults of the program as well as the successes. It is noteworthy that 23% of the problems in this program were not detected until integration tests were conducted which indicated, as the authors recognized, that interface conditions in subsystem test were not adequately simulated. Design reviews and test equipment reliability were also called out as areas where more emphasis was needed. An aspect of this program which may be of special interest to some readers concerns the special provisions required in the parts and materials program to meet the low ambient magnetic field requirement.

R70-15171 ASQC 813
HUGHES AIRCRAFT COMPANY LONG LIFE SPACE SYSTEMS
D. L. Lindstrom (Hughes Aircraft Co., Space Systems Div., Los Angeles, Calif.) WINCON 70, *Los Angeles, Feb. 1970, Paper* 14 p

Transition of communication satellites from 1963 to 1969 is described. Comparison of Syncom and TACSAT I is made. Feasibility of communication satellites and long life operation at high reliability were proven. Factors contributing to long life are derived. Accumulated data are tabulated. Author

Review: Reliability and program managers will find this paper interesting, as it gives a broad-brush discussion of a very successful reliability program and highlights those aspects of the program contributing to its success. The special procedures and practices described are not unique to this program, as separate examples of each can readily be found in other programs; it is their combined introduction that differentiates this program. It appears likely, however, that the incentive contracting feature contributed more (at least indirectly through its influence on other features) than the author recognized. The findings discussed on such things as the benign nature of the space environment, conservativeness of handbook failure rates, philosophy of using operational levels in acceptance testing, and management of the development and manufacture of new parts and materials will be especially interesting to many readers and will serve to substantiate the experiences of others. The author is certainly correct in asserting that the "reliability approach" must continue to be emphasized even though technology may change. The demonstration of long life capability is a significant feature of the paper, reflecting a considerable amount of space experience.

R70-15173 ASQC 810
MANAGEMENT TECHNIQUES FOR SYSTEM ELECTROMAGNETIC COMPATIBILITY
Anthony G. Zimbalatti (Grumman Aerospace Corp., ElectroMagnetic Compatibility Group, Bethpage, N.Y.) IEEE *International Convention, Technical Sessions, New York, Mar. 24, 1970, Paper* 32 p refs
(AV-EMC-GEN-R-291.0)

All complex systems use electrical/electronic subsystems which emit and are susceptible to various levels of radiated or conducted electromagnetic fields. If uncontrolled, these fields can produce electromagnetic incompatibilities that limit system effectiveness, or worse, endanger lives. Effective electromagnetic

compatibility programs for complex electronic systems require program objectives to be established, translation of objectives into design, control and test tasks, and execution of the tasks. Diverse electromagnetic compatibility technical skills, resources and facilities are developed, organized and assigned to the program. The management techniques used in a successful aerospace compatibility program are discussed. The major program tasks and milestones from contract award through production are presented and discussed. Author

Review: While this paper appears to present an operational management plan for implementing EMC, it could well apply to management of most any function. The paper is very uneven and lacks technical credibility as evidenced in the author's statement "*electromagnetic energy* (can) vary in meaning ... since it can include ... a diathermy heater, a television transmitter ...". *Energy* has an exact scientific interpretation and the author should have indicated that its *source* can vary. The paper is not particularly homogeneous in its presentation, since in one instance "the fundamental electrical problem" is defined as selecting a design to "produce desired effects" and "minimize interfering effects," while in another instance detailed diagrams of an anechoic chamber are presented. It is the reviewer's opinion that the management community *may* find interest in the paper, but that the technical community certainly will not.

R70-15179 ASQC 810; 830
SYSTEM ENGINEERING FOR INTERFERENCE REDUCTION
Anthony G. Zimbalatti (Grumman Aerospace Corp., ElectroMagnetic Compatibility Group, Bethpage, N.Y.) IEEE *International Convention, Technical Applications Sessions, New York, Mar. 25, 1970, Paper* 22 p refs
(AV-EMC-GEN-R-290.0)

All electronic/electrical equipments emit and are susceptible to various levels of radiated or conducted electromagnetic fields. The approach to establishing design requirements, management controls, and specifications for interference reduction in equipment is discussed. Examples of the importance of management controls, control plans, design reviews, and tradeoffs are presented. A program for compatibility is summarized to show the role of equipment interference reduction. Author

Review: The author directs his attention to a "systems approach" in a management structure for achieving an EMC program. The paper is clear, and although management-oriented, a brief review of it would serve the interest of the design engineer. It is fairly complete in defining the analytic tasks and discusses each task in sufficient detail so as to be a definite management aid. In this respect, the reader is directed to the other contributions of the author (listed in the references) for further treatment.

82 MATHEMATICAL THEORY OF RELIABILITY

R70-15183 ASQC 824
RELIABILITY ANALYSIS AND WHAT IT MEANS
Darrel T. Egly and William F. Esser (Consumers Power Co., Jackson, Mich.) (IEEE *Industrial and Commercial Power Systems and Electric Space Heating and Air Conditioning Joint Technical Conference, St. Louis, May 7–10, 1968, Paper* 4 p refs) IEEE *Transactions on Industry and General Applications,* vol. IGA-5, no. 5 Oct. 1969 p 578–581 4 refs *Its* Paper 68 TP 13-IGA

The use of probability techniques to calculate the reliability of any given system is becoming more commonplace in the electric-power industry. How reliability calculations, using basic interruption data and elementary arithmetic operations, can influence system design is demonstrated. Author

Review: This paper deals with elementary reliability statistics as applied to several simple examples. The constant hazard rate is presumed and all events are presumed to be statistically independent. Unfortunately, the latter assumption is implicit rather than explicit. Especially in transmission lines which are in close proximity to one another, one needs to convince himself by an appreciable amount of data and their analysis that the events are, in fact, statistically independent. For example, if the major source of damage were the weather, one might expect transmission lines not to be statistically independent in their failures. In many reliability papers on electrical power applications, reliability is used synonymously with availability (the fraction of time the system is up). In this paper, reliability is being used in the sense of probability of no failure, regardless of how long the failure might last. There is a little confusion between these two concepts in the authors' Example 1 where the critical problem is not the frequency of interruption but its duration. The duration is not considered at all in the example, only the frequency. Thus, only in its very general aspects should the paper be read for information; some of the details may be misleading.

R70-15187 ASQC 824
Finnish Academy of Technical Sciences, Helsinki.
THE LIFETIME OF SATELLITE 1958 ALPHA 1 (EXPLORER 1)
Risto Arho (Tech. Univ., Tampere) 1969 17 p refs *Its* Acta Polytech. Scand. Phys. Nucleonics Ser. No. 67
(N69-39138; Ph-67) Avail: CFSTI

In 1960 the decay of Explorer 1 was predicted to July 1962. In 1968 the total lifetime was given as roughly 11 years indicating the decay early in 1969. The error of the first lifetime determination was due to lack of knowledge of the effect of solar activity on atmospheric density. In this investigation the lifetime was predicted 26 October 1968. The prediction indicated the decay in May 1970. An error analysis gives an inaccuracy of 90 days. The attained result thus notably differs from the result of King-Hele, whose inaccuracy is due to overestimating the solar activity maximum of 1968 to 1969. An amendment of KING-HELE et al. dated 15 January 1969 gives for the decay data May 1970, which is consistent with the result of this paper. Author

Review: This well-written paper is concerned with the problem of predicting the time of decay of artificial earth satellites. The author's purpose is to present a method of lifetime calculation which involves numerical integration of the derivative of the orbital period rather than the equations of motion. A brief review of the limitations of previously proposed lifetime calculations is given. The author's calculation of the lifetime is more accurate than others when the satellite is subjected to periods of changing solar activity. The author demonstrates his method by predicting the date of decay of Explorer 1. This paper will be of value to others who must make similar calculations.

R70-15188 ASQC 821
Naval Postgraduate School, Monterey, Calif.
BLOCKING PROBABILITIES IN SMALL COMMUNICATION NETWORKS
John Mc Grath (M.S. Thesis) Dec. 1968 53 p refs
(N70-15985; AD-696068) Avail: CFSTI

Models are derived for small communications networks. Blocking probabilities are obtained for 2 terminal k-channel systems and compared with simulation results. Author (TAB)

Review: The probability of blocking is an important parameter in communications systems since this is the probability that the channel is busy when a call is placed. The purpose of this thesis is to model analytically the physical operation of a military communications system and develop the probability of blocking for systems with various degrees of complexity. The author's results apply to small communications systems manually controlled by operators at switchboards. A communications system is treated as a queuing model. Although the mathematics was not fully checked, the author handles the problem competently and adequately. The assumptions are explicitly made and are justified. (The two definitions of probability-of-blocking that appear are at variance--probably an editorial oversight.) This thesis is a good starting point for others who must make similar analyses.

R70-15191 ASQC 824
RELIABILITY ERROR DUE TO ASSUMED NORMALITY OF STRESS AND STRENGTH IN MECHANICAL SYSTEMS
Edward B. Haugen and Sharon Eckert (University of Arizona, Aerospace and Mechanical Engineering Dept., Tucson, Ariz.) *American Statistical Association Annual Meeting, 129th, New York, Aug. 19–22, 1969, Paper* 52 p refs

Critical re-evaluation of the foundation of design has pointed to the need for probabilistic methods that incorporate specified probability measures of adequacy, supported by the necessary design data described by distributions. It is assumed that steps up to and including the distribution synthesis of significant strength and stress have been taken. The possible error in reliability estimation due to the indiscriminate application of the theory, valid for normal strength and stress, is examined. It is concluded that there is a need to develop lognormal, not gamma, theory for probabilistic design. Author

Review: The contribution of this paper is in the presentation of some numerical calculations. They are similar to the kind that have appeared before wherein the robustness with regard to the particular distribution assumption is tested. The paper is quite straightforward except that part of the notation in the introduction is not clear. For example, the equation $k(\mu,\sigma) = (k\mu, k\sigma)$ is standard notation in referring to ordered pairs or vectors, but its relevance to normally distributed random variables is not clear. It has no effect on the results and is apparently a notation peculiar to a very limited group. The theory is quite elementary and straightforward, enough so that the few misprints occurring around equation 5 are of no consequence. The conclusions drawn from the numerical results are of interest, although they are naturally limited to the cases studied; namely, one of the distributions is *normal* and the other one is either gamma or lognormal. In practice, there is the usual difficulty that one has little knowledge of the exact shape of the distribution especially in the trail region that make the big difference in calculating reliability.

R70-15192 ASQC 824; 433
STRUCTURAL DECISIONS FOR CONSISTENT RELIABILITY ALLOCATION
Robert G. Sexsmith (Cornell University, Ithaca, N.Y.) *Engineering Institute of Canada Annual General Meeting, Vancouver, B. C., Canada, Sep. 9–13, 1969, Paper* 27 p refs
Grant NSF GK-3473

The proposed approach, based on concepts from Bayesian decision theory, provides a logical framework for consistent design decisions. This is achieved by considering consequences of the decision, in addition to data and judgment regarding strength. The probabilities that are considered are in the range of load for which data on strength are available. The decision-making aspect of engineering is explained. Author

Review: The author gives some interesting philosophy in his introduction, namely, that the civil engineer rarely has enough data upon which to base a strictly probabilistic design for high reliability. This is in contrast with the assertions of some, e.g., Kececioglu, who seem to have asserted otherwise for mechanical structures. The rest of the paper gives a good introduction to the Bayesian philosophy. It uses loss functions for arriving at a minimum-loss decision and uses the concept of the value of further information/testing. The paper does not give cookbook procedures but rather discusses the mathematical/statistical techniques which are available to designers. There is some jargon, especially with regard to civil engineering, but it is not objectionable. A person without any statistical background will be confused by the mathematics, therefore the paper can be of value to someone with a moderate statistical background but who is not familiar with subjective probability and who wishes to learn about it. (The author, in private communication, has stated that this paper is published in Transactions of the Engineering Institute of Canada, May 1970.)

R70-15194 ASQC 824; 838
ANALYSIS OF RESCUE SUCCESS IN EMERGENCY RETURN MISSIONS
S. T. Chu and A. R. Nagy, Jr. (Aerospace Corp., El Segundo, Calif.) *International Symposium on Science and Technology, 8th, Tokyo, Japan, Aug. 1969, Paper* 20 p refs

The question of successful rescue of spacecraft or escape capsule by combining the orbital waiting characteristics of the spacecraft and the capabilities of surface recovery forces is investigated. An analysis of return probability of spacecraft to multiple recovery areas is summarized. Considerations are given to factors of local time constraints and redundant access necessitated by limitations of weather, sea state, and visibility. An approach for the determination of probability of successful rescue is presented. This probability was obtained by matching of two independents, the return from orbit by the spacecraft and the search and rescue by aircraft. The method of analysis and information presented has broad applicability in program planning and conceptual studies of future manned space systems. Specific applications are, for example: determining design criteria for spacecraft; tradeoff studies in recovery planning; establishment of requirements for recovery forces; selection of recovery sites. Sample results of some typical applications are also included. Author

Review: This paper is related to the authors' reference 4 which was covered by R70-15098. The reference 4 dealt with the inclusion of local time constraints at the recovery sites and redundant access on spacecraft return probabilities. This paper, on the

other hand, investigates the question of successful rescue of spacecraft by combining the orbital waiting characteristics of the spacecraft and the capabilities of surface recovery forces. It will have the obvious uses in evaluating emergency procedures. The derivation involves concepts which are not familiar to most engineers, and if they wish to understand the derivation they will have to work at it. The calculations appear to be quite useful; there are several examples which show typical results. The authors have stated their assumptions well so there need be no ambiguity in applying the formulas. The material is, of course, specifically applicable to the problem of spacecraft emergency return. Sample applications are, for example: (1) determining design criteria for spacecraft; (2) trade-off studies in recovery planning; (3) establishment of requirements for recovery forces; (4) selection of recovery sites.

R70-15195 ASQC 824; 838

ESTIMATING THE RELIABILITY OF REDUNDANT SYSTEMS WITH CONSTANT RESTORATION TIME BY MEANS OF AN ANALOGY TO THE DIRECT LYAPUNOV METHOD

V. V. Kalashnikov *Engineering Cybernetics*, no. 3 June 1969 p 66–72 2 refs

By means of the direct Lyampunov method, generalized to the case of practically stochastic stability, the reliability of a redundant system with constant repair time of failed elements is estimated. Individual consideration is given to cases where the number of repair positions is equal to and is smaller than the total number of elements. From the estimates obtained asymptotic formulas are derived and compared with known formulas for exponential restoration laws.

Author

Review: This technique of approximation has not been discussed in the English-language literature, and thus the paper is of interest to reliability theoreticians. The author's reference 2, which is his first discussion of the method, will be virtually essential to an understanding of the paper. There are occasional misprints, but they can be uncovered by careful study. (Such careful study is necessary to an understanding of the paper in any event.) The paper is strictly a mathematical one and uses the format of theorem proving, thus the results are not accessible to the ordinary reliability engineer. At the end of the paper, the author comments that the bounds are not as close as they might be and that he expects to sharpen them in a future article. The quantity $F^{*n}(x)$ is not defined in the paper although it is used. It is apparently the probability that n or more items have failed during the period x. It would be worthwhile if someone would take the time to put this paper in a form more suitable for reliability engineers and publish it in one of the English-language journals.

R70-15201 ASQC 821; 831

ANALYSIS OF MISSION ORIENTED SYSTEMS

Herbert S. Winokur (Inner City Fund, Washington, D.C.) and Lawrence J. Goldstein (University of Maryland, Dept. of Mathematics, College Park, Md.) IEEE *Transactions on Reliability*, vol. R-18, no. 4 Nov. 1969 p 144–148 8 refs

(A70-28008)

Several measures of system reliability that are applicable to a mission-oriented or time-dependent system are defined: the probability that the system is in a given state at the end of a given mission phase; the probability density function of the random variable time spent in a state, given that the system has just transited into that state; the probability of mission success. Equations for these measures are derived, and an application of the formulas performed is discussed.

Author (IAA)

Review: Very simpleminded models for systems are often easy to calculate; the more exactly a model fits a given situation, the more complicated the calculations usually are. These are well-known tradeoffs in theoretical work, and the authors have chosen to create a more exact model which has much greater computational complexity and cost. (The work appears to be competent although not every equation was checked.) The parameters which were calculated are useful and in those situations where the need justifies the cost (and the model fits the experimental situation closely enough), the results of this paper can be used. Most of the references given in the paper are for historical purposes. The last reference, though, gives the details of a specific application of this system, and interested people will undoubtedly want to consult that reference. The technique now (over four years after the original final report) is much more standard than it was at the time the paper was written.

R70-15204 ASQC 822

ON FAILURE TIME DISTRIBUTIONS FOR SYSTEMS OF DISSIMILAR UNITS

Hisashi Mine and Shunji Osaki (Kyoto University, Kyoto, Japan) IEEE *Transactions on Reliability*, vol. R-18, no. 4 Nov. 1969 p 165–168 11 refs

Certain reliability problems of systems of dissimilar units with repair are described. The mean time to system failure is based on the relation of mean first passage times between states of the system. The failure time distribution is obtained from an integral equation of the renewal type. The two approaches can be also applied to a system of dissimilar units under an overload. Finally, it is shown that these results include many earlier results as special cases.

Author

Review: This paper will be of most value to theoretically-inclined reliability engineers and to those who are doing theoretical research on calculations of system failure-time. The authors claim their method is somewhat more general than others in use, and that some of the results in the literature are special cases of theirs. This assertion is borne out by their examples. The method involves the Laplace-Stieltjes transform and thus will be too sophisticated for a great many reliability engineers. Nevertheless, it will be helpful if reliability engineers are at least aware of the existence of this paper; then when they need calculations of this type made, they can refer their theoreticians to it and perhaps get the results much more quickly. The mathematics was checked in moderate detail, and appears to be quite competent.

R70-15207 ASQC 824; 433

BAYESIAN ANALYSIS OF THE WEIBULL PROCESS WITH UNKNOWN SCALE AND SHAPE PARAMETERS

Richard M. Soland (Helsinki School of Economics, Helsinki, Finland.) IEEE *Transactions on Reliability*, vol. R-18, no. 4 Nov. 1969 p 181–184 10 refs

(A70-28011)

The Weibull process with an unknown scale parameter was examined as a model for Bayesian decision making. The analysis is extended by treating both the shape and scale parameters as unknown. It is not possible to find a family of continuous joint prior distributions on the two parameters that is closed under sampling, so a family of prior distributions is used that places continuous distributions on the scale parameter and discrete distributions on the

shape parameter. Prior and posterior analyses are examined and seen to be no more difficult than for the case in which only the scale parameter is treated as unknown, but preposterior analysis and determination of optimal sampling plans are considerably more complicated in this case. To illustrate the use of the present model, an example is presented in which it is necessary to make probability statements about the mean life and reliability of a long-life component both before and after life testing. Author (IAA)

Review: This paper is an extension of the one covered by R68-13651. Both shape and scale parameters are treated as unknown, in contrast to the earlier paper, which dealt with estimation of the scale parameter only. This is an important extension, since it is often desirable to incorporate uncertainty about the shape parameter into the analysis. As in the earlier paper, the notation is quite complex, but the presentation is readable by anyone with a basic knowledge of Bayesian statistics. A concrete numerical example is included, and helps to clarify the method. (Clearinghouse document AD-687 289 contains the same material as this paper, plus an additional example.)

R70-15208 ASQC 824; 433

SOME BAYES ESTIMATES OF LONG RUN AVAILABILITY IN A TWO-STATE SYSTEM

Donald P. Gaver, Jr. (Carnegie-Mellon University and Westinghouse Research Labs., Pittsburgh, Pa.) and Mainak Mazumdar (Westinghouse Research Labs., Pittsburgh, Pa.) IEEE *Transactions on Reliability*, vol. R-18, no. 4 Nov. 1969 p 184–189 6 refs
(TN3356)

Some Bayes estimates are obtained of an index of performance of a system that alternates between two states, up or down, in accordance with a Markov process. The index considered is long-run availability, which measures the probability that the system will be up when needed. For the purpose of obtaining these estimates, two types of observations are considered: those that reveal only the state of system at isolated time points and those that continuously record the duration of the up and down times of the system. Author

Review: This is a theoretical paper. It will be most helpful to the theoretically inclined reliability engineer who is trying to find ways of using prior information in estimating availability. Both the prior knowledge assumptions and the loss functions which are tested are not unreasonable. Given the prior knowledge assumptions and the loss functions, the balance of the paper is a fairly straight-forward application of Bayesian statistics. Some of the mathematics is too sophisticated for reliability engineers; for example, many engineers are not familiar with the hyper-geometric function. The numerical results themselves are of interest without regard to the detailed theory used in deriving them. The authors discuss these results very realistically and readers can understand them without having gone through the entire paper.

R70-15209 ASQC 824; 822

COMPLETE SAMPLE ESTIMATION TECHNIQUES FOR REPARAMETERIZED WEIBULL DISTRIBUTIONS

G. Arthur Mihram (University of Pennsylvania, Moore School of Electrical Engineering, Philadelphia, Pa.) IEEE *Transactions on Reliability*, vol. R-18, no. 4 Nov. 1969 p 190–195 16 refs
(A70-28012)

Two fundamental reparameterizations of the Weibull probability density function are proposed. The first reparameterization replaces the shape parameter by its inverse, the resulting positive parameter thereafter termed the shaping parameter. This permits a more facile exposition of the properties of parameter estimates, derived in the event that a complete random sample from the Weibull distribution is available. The characteristics of these parameter estimation techniques are then reviewed and compared, and their variances and distributional properties are delineated whenever possible. A second reparameterization extends the parameter space so as to include nonpositive values of the shape parameter. This extension augments the utility and applicability of the Weibull distribution without requiring radical alteration of the standard parameter estimation procedures applicable to the original parameter space. Author (IAA)

Review: This paper is primarily for statisticians. The discussions of the various estimates will be of little concern to a reliability engineer or a designer, save for a new graphical estimation technique which is developed for the Weibull shaping parameter. Nevertheless, the distribution is important in reliability, and investigations of it may eventually improve the ability of reliability engineers in using this distribution in practical situations. The statistics was not checked in detail, but it appears to be quite competent. Statisticians with an interest in the Weibull distribution will find this paper valuable for the somewhat different insight it gives.

R70-15213 ASQC 821

TRUE RELIABILITY VERSUS INSPECTION EFFICIENCY

R. A. Blais (Lockheed Missiles and Space Co., Sunnyvale, Calif.) IEEE *Transactions on Reliability*, vol. R-18, no. 4 Nov. 1969 p 201–203
(A70-28014)

It is shown that in certain hardware programs the product reliability can be explicity related to the efficiency of manufacturing operations. The reliability can also be implicity related to the design margins for the product. Expressions are derived that relate these parameters to both product reliability and product acceptance rate. A method is suggested for measuring and inspection efficiency so that an upper limit to product reliability can be derived from product-acceptance data. IAA

Review: This paper attempts to use probability theory to describe some of the errors occurring during the inspection phases in a manufacturing process. It provides a modest amount of insight, in that the results were not completely obvious from the assumptions. One of the big difficulties, as the author points out, is that there are not sufficient data on the production inspection processes in order to use the model. Production and reliability engineers may be able to get some good ideas from the paper, and it should be read in that sense.

R70-15214 ASQC 821; 412

ON PREDICTING FAILURES IN A FUTURE TIME PERIOD FROM KNOWN OBSERVATIONS

B. V. Shah (Research Triangle Institute, Research Triangle Park, N.C.) IEEE *Transactions on Reliability*, vol. R-18, no. 4 Nov. 1969 p 203–204 11 refs

The problem of a prediction interval for the number of failures of a system during a future time period knowing the failures observed during a time interval in the past is considered. It is assumed that the failures follow a Poisson process. Now, if the failures in both time intervals were known, they could be used to test the hypothesis that the two observations were generated by the same Poisson

law. By appropriately inverting the inequalities for the critical region of the above test, it is possible to generate the prediction limits for the number of failures in one time interval by observing the failures in the other time interval, provided both observations are subject to the same Poisson law. Author

Review: The main value of this paper to reliability engineers will be in introducing them to the prediction interval. One of the valuable functions statistics performs in engineering is to emphasize the uncertainty of the result of a test and the uncertainty of a prediction. This technique helps to make those uncertainties explicitly clear in the case of a Poisson distribution. No direct tables are provided, and it will be somewhat tedious getting the required information indirectly, from the referenced tables, although the author's examples are clear. However, in the special case of no-failures-in-the-interval (a common situation), no recourse to tables is necessary. The author's reference 10 is a company report; it is on the publication schedule for a future issue of the same journal and when it does appear may be the more valuable of the two references since it contains curves for making the calculations. While the technique and concepts have been in the statistical literature for some time (as shown by the author's references), even statisticians occasionally need to be reminded of techniques which are at their disposal.

R70-15215 ASQC 824

A NOTE ON STRESS STRENGTH RELIABILITY MODELS

Ramachandran Subramanian and Kodumudi Subramaniam Ramesh (Indian Institute of Technology, Dept. of Mathematics, Madras, India) IEEE *Transactions on Reliability*, vol. R-18, no. 4 Nov. 1969 p 204–205 6 refs

The general theory of stochastic point processes is applied to construct the reliability function for some stress-strength models. Author

Review: This short note extends some of the calculations for the stress-strength model of failure. It can include cumulative damage. The paper will be useful for theoretically-inclined reliability engineers who are trying to find a unifying framework within which to use a theory of failure. Most of the equations were checked and none were incorrect. The paper can also provide a useful place for theoretically-inclined reliability engineers to pursue this kind of model for failure. There is little of direct value for design engineers.

83 DESIGN

R70-15175 ASQC 830

CONTROL OF SIGNAL PATH TO REDUCE UNWANTED PICKUP

O. M. Salati (Pennsylvania Univ., Moore School of Electrical Engineering, Philadelphia, Pa.) IEEE *International Convention, Technical Applications Sessions, New York, Mar. 25, 1970, Paper* 22 p refs

Electrical interference may be divided into three categories: a source of unwanted signal or a disturbing circuit, a coupling path and a disturbed circuit or device. Emphasis is placed on coupling paths which may be cables, coaxial lines or waveguides. Unwanted signals may enter the desired signal circuit by way of mutual electrical components such as resistors, capacitors, inductors, or transformers; by reactive fields; by electromagnetic radiation; by charge redistribution as a result of mechanical motion; by magnetostriction; or as a consequence of the use of dissimilar metals with resulting contact potential, thermo-electric phenomena or nonlinear action as a result of corrosion. Methods presented for minimizing these defects include: shielding, physical separation of circuits, grounds, bonds, filtering, balanced circuits, cancellation techniques, cable length and terminations and circuit impedances. Author

Review: This paper presents an expository review of techniques for reducing channel (wire) interference. The recommendations for achieving this reduction are clearly presented for a wide spectrum of techniques. The discussion is not highly technical; however, it is directed toward a fairly competent technical audience. While the author does not explicitly indicate the source of his recommendations or his data (figures), he does say that they can be found among the comprehensive list of references accompanying the paper. The entire problem is important to electronics reliability, and will become more so with the increasing sophistication and complexity of electronic gear. In a private communication, the author has indicated that Figures 1, 2, 7, 10, 11, and 12 were developed for the paper. Figures 4, 5, and 6 are from Reference 31, Figure 3 was adapted from R. B. Schulz, "Lecture Notes on EMC," Moore School of EE, Special Summer Session 1965, Figure 8 is from NASA Apollo Program, NHB 5320.3, Oct 65, "EMC Principles and Practices," and Figure 9 is from O. M. Salati, "Training Course in EMC," Feb 66 for Electromagnetic Environment Division, U. S. Army Electronics Command, Fort Monmouth, N.J.

R70-15178 ASQC 838

Air Force Systems Command, Wright-Patterson AFB, Ohio. Foreign Technology Div.

THE PROBLEM OF THE INFLUENCE OF AUTOMATIC MONITORING ON THE RELIABILITY OF SYSTEMS WITH REDUNDANCY

T. D. Zolkover 2 Sep. 1969 11 p refs Transl. into ENGLISH from Akad. Nauk SSSR Sibirsr. Otd., Tr., (USSR), no. 1, 1966 p 96–100 (N70-18450; AD-696164; FTD-HT-23-291-68) Avail: CFSTI

Systems with active parallel redundancy in which reserve elements (RE) are controlled by check-and switchover (ChS) units is considered. A set of differential equations describes the reliability conditions in terms of failure rates and r sub m (probability that a branch failure is accompanied by elimination or self-elimination of RE). As a result, the probability of successful operation of the entire system is determined. These particular cases are considered: (1) failure rates are constant in time (exponential law of distribution of reliable-operation time); (2) a definite ratio of failure rates of RE and ChS; (3) reliability characteristics of RE and ChS do not change when the number of branches changes; starting from a certain value of the redundancy rate, the probability of successful operation decreases. When the probability of RE self-elimination is sufficiently high, ChS devices are superfluous. TAB

Review: This translation from the Russian is directed primarily toward theoreticians. The authors' objectives are: (1) to derive the equations for optimizing the reliability of systems with parallel redundancy (including monitoring and switching devices for removing faulty redundant elements from the system's structure) and (2) to examine particular cases under special assumptions. The approach is technically sound; however, the U. S. reader must overcome some obstacles in following the mathematics, probably due

to the translation (e.g., undefined symbols). Although the results of this paper are well known, the material itself serves to clarify the making of reliability calculations of this nature.

R70-15184 ASQC 830
UNINTERRUPTABLE POWER FOR CRITICAL LOADS
Alfred E. Relation (Electric Storage Battery Co., Exide Power Systems Div., Raleigh, N.C.) (IEEE *Industry and General Applications Group Annual Meeting, Chicago, Sep. 29-Oct. 3, 1968, Paper* 6 p refs) IEEE *Transactions on Industry and General Applications*, vol. IGA-5, no. 5 Oct. 1969 p 582–587 6 refs *Its* Paper 69 TP 6-IGA

A description of the design and performance of high power thyristor inverters for uninterruptable power systems is presented. These inverters have been designed to provide precisely regulated and continuous ac electrical power for critical loads, such as real-time data processing computers, air route traffic control centers, and industrial process control equipment. High reliability, over 80,000 hours MTBF, is achieved by utilizing a parallel redundant system configuration. Systems have been designed with ratings of up to 2000 kVA. Typical instantaneous voltage transient limits are plus 10 and minus 10 percent. Frequency tolerance is plus or minus one-half percent. Total harmonic distortion is less than t percent rms. Author

Review: This paper describes a dual concern for reliability. First, the operating equipment has a stringent reliability requirement, and second, the equipment must therefore be reliably supplied with ac power. It is to the latter problem that the paper is specifically addressed. An example of the former is the study by NASA which shows that disturbances of less than one tenth of a cycle (of ac power) can adversely affect a computer. The paper shows why a continuously operating static inverter was chosen to supply the entire load. Reliability was achieved by using high reliability parts, by using redundancy, and by being sure that failed subsystems were prevented from adversely affecting the system. The last point is one most often neglected in elementary analyses of redundancy; the conceptual frame work is easy, but the actual implementation of it is often difficult. Thus, in a sense, this paper is a general description of a case history showing how the reliability discipline has been applied, and it is useful for that purpose as well as for those who are specifically interested in reliable ac power supplies.

R70-15186 ASQC 830; 813
National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.
THE IMPROVEMENT OF AN ELECTRONIC POWER SUPPLY FOR GREATER RELIABILITY IN AEROSPACE USE
John P. Quitter and J. W. Schaelchlin (Gen. Dyn./Convair, San Diego, Calif.) Washington Sep. 1969 47 p refs
(N69-35763; NASA-TM-X-1875) Avail: CFSTI

This report is a brief account of an upgrading program for electronic equipment. Serious design obstacles were overcome that led to the successful development of a highly reliable electronic component for space use. The component discussed is an inverter that provides three-phase 400-Hz power to the Centaur space vehicle. Because of early ground failure and design deficiencies, the inverter has received much engineering attention. This report is concerned with general upgrading of all piece parts used in the inverter, as well as improved mechanical and thermal design. Weaknesses of original piece parts are described, and rationale presented for the choice of better parts. Author

Review: This report discusses a program undertaken in order to improve the reliability of the power supply of the Centaur space vehicle. Failure of the power supply in flight would remove ac power from the Centaur guidance system, resulting in loss of mission. The report is oriented toward design engineers and applies to a large class of electronic systems employing parts similar to those used in power supplies. It is this sort of report that design engineers need, yet rarely find, since case histories of this nature are seldom documented. The report serves the following two major purposes: (1) it points out the problems encountered and the solutions found in order to achieve a highly reliable design and (2) it shows the necessity of good engineering in both the electrical and mechanical aspects of a design as well as the interrelationships between these areas. The report is well organized, highly readable and will be useful in helping designers avoid many pitfalls.

R70-15193 ASQC 831; 615; 817
OPTIMAL DESIGN OF MULTICOMPONENT SYSTEMS WITH RELIABILITY AND CONGESTION REQUIREMENTS
Wah-chun Chan (University of Calgary, Dept. of Electrical Engineering, Alberta, Canada) *Engineering Institute of Canada Annual General Meeting, Vancouver, B. C., Canada, Sep. 9–13, 1969, Paper* 12 p refs
Grant NRC A-5127

In the design of multichannel communication systems of data processing systems a basic requirement is that of constructing a system with high reliability, low cost and small congestion. The study of optimal design of a class of problems arising in the design of multicomponent systems with various physical constraints, such as reliability, cost, weight and congestion is discussed. By virtue of the method of dynamic programming the formulations of a maximum reliability problem and a minimum cost problem are presented. Author

Review: It is not clear wherein the contribution of this paper lies. The formulation of the reliability of a series-parallel system is well established. The cost and weight functions used by the author are simple linear ones. The problem of optimizing the situation has been treated by many authors; see, for example, the Proceedings of the Annual Symposia on Reliability. The problem is fully solved by Kettelle (Operations Research, vol. 10, 1962, pp. 249–265) and by Proschan and Bray (Operations Research, vol. 13, no. 5, 1965, pp. 800–814) using the dynamic-programming technique. The author does not seem to add much. In fact, Proschan and Bray also give detailed flow-charts for a computer program. The use of Lagrange multiplier to reduce the number of constraints is standard and well-known. A Lagrange multiplier is introduced to eliminate one of the variables, although it introduces the unknown Lagrange multiplier (so where is the simplification?). The author does not have any new ideas for simple ways of finding the optimum value for the Lagrange multiplier. Clearly, the problem is of practical importance as suggested by the author in his conclusions. One is not much further along toward its solution at the end of the paper than he was at the beginning, given the state-of-the-art.

R70-15205 ASQC 831; 612
AN ALGORITHM TO DETERMINE THE RELIABILITY OF A COMPLEX SYSTEM

Paul A. Jensen (University of Texas, Dept. of Mechanical Engineering, Austin, Tex.) and Mandell Bellmore (John Hopkins University, Dept. of Operations Research and Industrial Engineering, Baltimore, Md.) IEEE *Transactions on Reliability*, vol. R-18, no. 4 Nov. 1969 p 169–174 10 refs
(A70-28009)

The method most often suggested for determining the reliability of a system is to construct a reliability network, enumerate from the network all mutually exclusive working states of the system, calculate the probability of occurrence of each working state, and sum these probabilities. For a complex system this is not a practical method for there is a very large number of working states. Esary and Proschan suggest a lower bound approximation to reliability that requires the enumeration of a much smaller set of system states. These states are called minimal cuts. An algorithm is presented to determine the set of minimal cuts and thus calculate a lower bound to system reliability. The algorithm is intended for digital-computer implementation and computational times are provided. Author

Review: The contribution of this paper is to present an algorithm for generating minimal cuts in a network. The algorithm was not checked/verified by the reviewer on a computer, but it does appear to be reasonable. The paper will be of value to computer programmers and reliability engineers who are preparing problems for computer programmers in calculating this kind of figure of merit. The method is not compared with other algorithms for doing the same thing, and in general such comparisons are difficult. This same journal has other papers scheduled for publication which deal with a similar topic (see IEEE Spectrum, May 1970).

R70-15206 ASQC 838; 844
THE EFFECT OF PARTIAL FAILURE MODES ON RELIABILITY ANALYSIS
Jon A. Jenny (Electromagnetic Systems Lab., Sunnyvale, Calif.) IEEE *Transactions on Reliability*, vol. R-18, no. 4 Nov. 1969 p 175–180 6 refs
Grant NSF GA-1195
(A70-28010)

An analysis is presented of the effect of partial failure modes on the calculation of an optimum amount of redundancy. (Partial failure modes are modes that are catastrophic to the part but not to the system.) The analysis is limited to systems that are not repaired, whose performance can be measured with a one-dimensional capacity index, and that are composed of parts that fail in only one mode. The problem is formulated in terms of loss coefficients and state probabilities and a model is given to organize computation of the state probabilities. The analysis is incorporated into a redundancy optimization program so that, for the first time, optimal redundancy can be calculated for systems with partial failure modes. This program is applied to an example system and the results are explained. It is shown that the partial failure mode analysis will always yield a lower expected loss, will thus require less redundancy, and hence will yield a lower initial system cost than the equivalent total failure-mode analysis. Author (IAA)

Review: Under many circumstances, particularly in aerospace missions, the concept of partial success is essential to determining a useful, reliability-like figure-of-merit for a system. This concept has been treated in the literature, for example in terms of *value*, where value is a number between 0 and 1 rather than being forced to be either 0 or 1 (reliability is of the latter form). This paper treats a similar situation in terms of loss coefficients which indicate the fraction of capacity that is lost on failure of a component. The treatment is adequate: there are no apparent errors and the several examples make it quite clear what the author is doing. For those who have not been introduced to this subject before, the paper will be a good tutorial presentation.

R70-15210 ASQC 838
A THREE COMPONENT REDUNDANCY PROBLEM
Naunihal Singh (Monash University, Dept. of Mathematics, Clayton, Vic., Australia) IEEE *Transactions on Reliability*, vol. R-18, no. 4 Nov. 1969 p 195–197 2 refs

A way of solving for the probabilities of various states of a redundant system with three components is shown. The failure rate of each component is a constant but the repair function is arbitrary. The method of solving the integral equations is by using Laplace–Stieltjes transforms. Author

Review: This short paper can serve the purpose of introducing reliability engineers to a technique for solving certain kinds of problems. It is also an illustration of the solution of one particular problem. Only very occasionally will one have a situation that fits this model closely enough. Since the repair function is arbitrary, the results are in a general form. Those results, given only in terms of the Laplace–Stieltjes transform, must be inverted (unless only long-range probabilities are of interest) to be of practical value. This inversion greatly restricts the form of the repair function if in fact the results are to be tractable. The mathematics was checked and is correct (aside from an obvious misprint at the bottom of page 196 in the table).

84 METHODS OF RELIABILITY ANALYSIS

R70-15169 ASQC 844
Advisory Group for Aerospace Research and Development, Paris (France).
STRESS CORROSION. PART 1: PRACTICAL CONSIDERATIONS
G. B. Evans (Hawker Siddeley Aviation LTD., Hatfield, Engl.) 1968 48 p refs
(N70-11481; AGARD-570) Avail: CFSTI

The report is a study of the present position on stress corrosion from the point of view of designers and constructors, made during 1968 for the AGARD Structures and Materials Panel. The survey is divided into two parts: Part I is a collection of information and views obtained by the author by written questionnaire and visits and is intended for designers and production personnel in the aerospace industry. Part 2 contains a summary of areas within the field of stress corrosion to which further research could be usefully directed, in addition to the pure research currently proceeding on the behavior of surfaces and the various mechanisms of cracking involved. This part is intended for the AGARD Structures and Materials Panel, and will not be available for general distribution. Author

Review: This is a good report; it is lamentable that it has taken over a year to find its way into relatively public distribution since it deals well with such an important topic in the area of reliability. The format of the paper is generally one of a summary of replies to a questionnaire along with pertinent and worthwhile

comments by the author. Thus, it is not just the raw data being handed back but carefully treated summaries of the data. The author points out that most aerospace people connect the phenomenon with aluminum alloys although there is some reference to titanium. It is also interesting to note the consensus about the low-strength alloys not having this problem whereas the very high-strength alloys are most susceptible. It is not unlikely that this may be true with other metal systems as well, viz., the more carefully the metal system is "bred" for higher strength in one property, the more susceptible it becomes to other failure mechanisms. The report should be carefully considered by those who are responsible for the mechanical/metallugrical design of aerospace systems. The author expresses his comments well; he is rarely categorical and he tries to give an understanding of the various points of view rather than to grind his own personal axe.

R70-15174 ASQC 844; 612
Wolf Research and Development Corp., Bladensburg, Md.
A SURVEY OF CURRENT DEBUGGING CONCEPTS
Wallace Kocher Washington NASA Aug 1969 89 p refs
(Contract NAS5-9756-99)
(N69-35613; NASA-CR-1397) Avail: CFSTI

The debugging of computer programs is analysed in terms of the localization and correction of errors. Current debugging concepts are presented with only logical and clerical errors considered. The computer program for the Interplanetary Monitoring Platform is documented with emphasis placed on the error diagnostic procedures. Proposals for developing software that will allow debugging to be conducted using language as the source program are included. F.O.S.

Review: Debugging techniques are to software what failure modes and effects analyses are to hardware. Furthermore, the reliability of computerized systems is as dependent on software as it is on hardware. This comprehensive report documents the debugging effort on the Interplanetary Monitoring Platform program and surveys current computer-program debugging concepts. Of the various phases of program debugging, the author emphasizes error diagnostic procedures. Both logical and clerical errors are considered; however, no consideration is given to machine malfunctions. Some knowledge of program debugging is required before reading this report. The author has succeeded in compiling a great deal of usable information regarding programs and programming techniques for debugging. Both programmers and managers concerned with this subject will find much value in the author's discussion on the advantages and disadvantages of various debugging languages and methodologies currently in use. The author might have improved the report by defining needed terms, e.g., tracing, postmortem dump, snapshot dump, prior to their usage. This report will help readers to become abreast of the state-of-the-art and serve as a checklist for carrying out both conventional and on-line debugging.

R70-15180 ASQC 844
National Aeronautics and Space Administration. Langley Research Center, Langley Station, Va.
THE ROLE OF STRESS CONCENTRATIONS IN STRUCTURAL FATIGUE
John H. Crews, Jr. (Ph.D. Thesis - Va. Polytechnic Inst.) May 1969 155 p refs
(N69-41185; NASA-TM-X-61969) Avail: CFSTI

An analysis of fatigue behavior at stress-concentration sites is presented for sheet specimens containing a central hole under remote uniaxial cyclic loading. This investigation was conducted in three phases: (1) analysis of local cyclic stress-strain conditions at the stress-concentration site; (2) study of fatigue crack initiation; and (3) study of the initial stage of propagation for cracks growing from the stress-concentration site. The generally close correlation between calculated and observed results demonstrated the utility of local stress analyses in the prediction of fatigue behavior for structural components containing stress concentrations. The procedures used are expected to be generally applicable for fatigue analyses involving more complicated configurations and loading.
Author

Review: This is a scholarly presentation of the topic as befits a Ph.D. thesis; therefore the results are directed toward the research worker rather than toward design and reliability engineers. The author has treated an interesting and useful topic although the thesis itself is much more narrowly construed than might be inferred from the title. Since fatigue is such an important failure mechanism in aerospace vehicles, any competent research on the subject is a useful addition to the growing literature. An understanding which is both basic and amenable-to-engineering-calculation still eludes us; this thesis is a small but helpful step in the direction of filling the gap. The author stops just short of where fracture mechanics usually begins.

R70-15181 ASQC 844
Air Force Systems Command, Wright-Patterson AFB, Ohio. Foreign Technology Div.
FEATURES OF FATIGUE DIAGRAMS UNDER FRETTING-CORROSION CONDITIONS
V. N. Stepanov 18 Mar. 1969 8 p refs Transl. into ENGLISH from Fix.-Khim. Mekhan. Materialov (USSR), v. 3, no. 3, 1967 p 282–285
(N70-20904; AD-697604; FTD-HT-23-1153-68) Avail: CFSTI

The perculiarities of a fatigue diagram under fretting-corrosion conditions are examined: a method of the accelerated construction of the diagram is proposed, based on the known criteria of cyclic strength and also on the resultson an investigation made for the cyclic strength of steels OKhN3M, St. 10, 65G and other material.
Author

Review: The author makes essentially two points: (1) There are two parameters which determine the fatigue curve for a given alloy (they form the basis for the energy criteria of cyclic strength). (2) The influence of fretting corrosion is such that if this fatigue curve is extrapolated back to one-quarter cycle, fretting causes the fatigue curve to be rotated downward. The heretofore horizontal part (the fatigue limit) now slopes downward; typical angles of rotation are about a tenth of a radian. These angles are determined by running a few points near the break in the fatigue curve but at slightly higher loads. This entire method of presentation of the fatigue data seems to ignore the considerable scatter which exists, nor is it universally accepted that two parameters determine the basic fatigue behavior of an alloy. Nevertheless, the results are interesting; they may suggest ideas for further research and, if designers have absolutely no other information to go on, they can try to apply the ideas of this paper.

R70-15182 ASQC 844
EFFECT OF DISCONTINUITIES ON FATIGUE PROPERTIES OF ALUMINUM WELDS
M. S. Hersh (General Dynamics Corp., Convair Div., San Diego,

Calif.) *Welding Journal, Research Supplement,* vol. 48, no. 9 Sep. 1969 p 389-S to 394-S ref
(A69-42940)

Study of the effect of porosity and inclusions on the fatigue properties of aluminum weldments at ambient and cryogenic temperatures. Automatic welds and manual repair welds were evaluated. The material, 0.100 in. thick 2219-T81 aluminum alloy, was gas tungsten-arc welded with 2319 aluminum filler metal and postweld-aged. Specimens chosen for studying the effects of isolated, clustered, and tailed porosity and inclusions were categorized as the severity of defects. Linear porosity and inclusions were not studied, since previous work had shown that linear defects severely reduce fatigue properties. Defects in the automatic welds were produced by graphite pencil markings and in the manual repair welds by an increase in electrode holder gas pressure along with graphite pencil markings. Author (IAA)

Review: This research seems to have been well motivated, well planned and carried out, and well reported. While the experienced engineer is quite aware of the problems welds can cause, the young engineer is often less so. This is especially true of reliability engineers who have not come up through mechanical and metallurgical engineering. The problem of "when is a defect not a defect" is being discussed more extensively in the literature, especially now that nondestructive evaluation methods are becoming much more sensitive. There has been an increasing number of complaints in the literature that (1) many specifications were overly severe and (2) deviations from idealness much greater than those heretofore allowed by the specification are not detrimental. This paper will be of value to a wide spectrum of aerospace engineers ranging from metallurgists to reliability practitioners.

R70-15185 ASQC 844
Aeronautical Research Labs., Melbourne (Australia).
THE EARLY DETECTION OF FATIGUE CRACKING
I. G. Scott Feb. 1969 13 p refs
(N69-38944; ARL/MET-62) Avail: CFSTI

Methods suitable for the detection of fatigue cracking are described and discussed. It is concluded that although the sensitivities of existing methods are probably adequate, more knowledge about the fatigue process is needed before positive identification of early fatigue cracking becomes possible. Author

Review: This paper is short, relatively easy to read, and provides a somewhat different perspective on the problem than is usually given by those doing narrow research in fatigue crack detection. Those researchers usually point out the extreme sensitivity of their own method for detecting cracks. This author suggests that those methods can also then detect cracks which are not due to fatigue. The paper consists mainly of a review of various methods of crack detection. It is a useful and reasonably objective summary. At least some researchers would probably argue that it is not necessary that the cracks they detect be caused by fatigue, that fatigue cracks can propagate from the discontinuity they observe. This is an area in which the ratio of engineering judgment to fact is extremely high, and statements on the subject are usually those of faith, not widely accepted knowledge.

R70-15189 ASQC 844
Bendix Corp., Holmdel, N.J. Semiconductor Div.
SAFE OPERATING AREA DETERMINATION FOR PREVENTION OF SECOND BREAKDOWN
[1969] 185 p
(Contract NAS8-21155)
(N69-37780; NASA-CR-102250) Avail: CFSTI

The true dynamic characteristics of selected power transistors used in critical space applications were determined. Using the safe operating area (SOAR) principle, transistor parameters in all operating and breakdown situations were tested. The purpose of these evaluations is to assist in the application, selection, performance, and the reliability of semiconductor devices in critical NASA systems. Ten n-p-n silicon power transistors were evaluated for SOAR in six critical functions; actual power handling capability for each type was determined. From the manufacturer's specifications, test curves, and SOAR evaluation, recommendations were made to design personnel and for the use of manufacturer's in better device selection. M.H.E.

Review: This document is a compilation of safe operating area (SOAR) curves for selected power transistors used in critical space applications. The curves are based on measurements of individual devices made by individual manufacturers and have in the past successfully specified regions of circuit operation free from second breakdown. The publication is an indispensible reference for the designer using these devices but will be of little interest to other readers.

R70-15196 ASQC 844
International Business Machines Corp., Owego, N.J. Federal Systems Div.
EFFECTS AND DETECTION OF INTERMITTENT FAILURES IN DIGITAL SYSTEMS
M. Ball and F. Hardie [1969] 26 p refs Presented at Fall Joint Computer Conference, 1969
(Rept-69-825-2435)

The effects of intermittent faults were analyzed via a logic simulator and over 500 hours of computer time. To evaluate the detectability of classes of failure rather than to develop specific techniques for failure detection is the intent. The simulated intermittents varied in duration from 500 nanoseconds upward. More than one-half million intermittent failures were simulated. The sensitivity of the logic to intermittent failures versus logic class and probability of detection versus test program length are reported. Author

Review: This is a good well-organized, well-written paper which devotes needed attention to intermittent faults in digital systems. The study is based upon a logical simulation of the Saturn V Launch Vehicle digital computer. The authors have two purposes: (1) to determine the effects of intermittent failures on the computer's operation and (2) to evaluate the detectability of classes of failures. Neither mechanisms of failure nor techniques for detecting intermittent faults are considered. Several results which system designers will find useful are given. One interesting result (although based upon a relatively small statistical sample, as pointed out by the authors) is that less than 10% of the total simulated failures caused the logic to perform incorrectly. The paper would have been more valuable if there had been more discussion on the causes of this fault masking. Since almost all of the literature in this area is confined to the case of solid faults, this paper ought to be read by everyone having an interest in the design of reliable digital systems. The reader should not attempt to generalize the authors' results without carefully evaluating the situation.

R70-15197 ASQC 844; 775

INFRARED AS A TERMAL ANALYSIS TOOL

Mary L. Rauhe and Herbert E. Randall (International Business Machines Corp., Federal Systems Div., Electronics Systems Center, Owego, N.Y.) *Solid State Technology*, vol. 13, no. 3 Mar. 1970 p 67–72; 187 7 refs

The basic theory of infrared radiometry is reviewed. Applications of infrared measurements at the electronic component and assembly levels are discussed. Applications include emissivity measurements on structures and components, defect location in multilayer printed circuit components. Semiconductor junction temperatures on integrated circuits have been successfully measured by means of an infrared microradiometer. A review of some of the current infrared measuring equipment, including advantages and limitations, is presented. Author

Review: This paper is an introductory review of infrared methods in electronic circuit analysis and troubleshooting. The discussion begins with first principles and goes on to describe contemporary measuring equipment based on these principles. The paper is well organized and easy to follow. The illustrations of (1) short-circuit location on a multilayer interconnection board and (2) integrated circuit temperature measurement show the usefulness of these techniques nicely. The paper is intended for the novice wishing to learn about infrared methods in electronics. The reader familiar with such methods will not find any surprises.

R70-15198 ASQC 844; 775

APPLICATION OF SCANNING ELECTRON MICROSCOPY TO INTEGRATED CIRCUIT FAILURE

John R. Devaney (Jet Propulsion Lab., Pasadena, Calif.) *Solid State Technology*, vol. 13, no. 3 Mar. 1970 p 73–77

NAS7-100

Investigations concerning ball bond contamination and open metalization at contact windows are outlined. The results indicate that insufficient cleaning of the bonding wire after drawing is the source of chlorine residues on the bond. The open metalization problem has been resolved by a change in the oxide profile by the integrated circuit manufacturer. Author

Review: The scanning electron microscope (SEM) has been the subject of a number of impressive and strikingly illustrated papers showing it as an analytic and diagnostic tool. This paper, while very brief, is a worthy addition to the existing list of high quality publications. The following two failure modes/mechanisms are discussed: (1) contaminants from the gold wire used in ball bonding, and (2) metallization opens at an oxide step. The first mode has not been described in the literature previously and is illustrated beautifully by a series of striking secondary electron micrographs which show contaminants "bleeding" from a gold ball bond and/or coating the base of the bond and interfering with the metallurgical and electrical contact between the gold and the aluminum. This example is an impressive demonstration of the power of the SEM in failure analysis. The illustrations make the failure appear so obvious that it is difficult to believe that these conditions could have existed and escaped detection previously, yet the evidence given here suggests that ball bond contamination has been and still is a very common problem with gold-ball bonded silicon devices. (Aluminum to aluminum bonds were found not to degrade because of the ultrasonic scrubbing used in making such bonds.) The solution is evidently one of improved cleaning, but no specific recommendations are made as to how to achieve cleaner gold bonding wire. Sodium chloride crystals were also observed around the periphery of certain bonds and were attributed to contaminants from fingering, indicative of improper process quality control. The second failure mechanism investigated was that of opens at a contact window. The use of voltage contrast to determine which leads are open is illustrated. Using the SEM to carry out this determination avoids unnecessary handling and probing which could be damaging. This use of the SEM has been recognized previously (see the paper covered by R65-11980). The present paper confirms the practicality of such a role.

R70-15199 ASQC 844

FAILURE ANALYSIS AS A TOOL FOR DETERMINING SEMICONDUCTOR SCREENS

J. L. Latour (Associated Testing Labs., Inc., Wayne, N.J.) *Solid State Technology*, vol. 13, no. 3 Mar. 1970 p 84–87

To eliminate failed components prior to use in a system, a screening program must be conducted. For a screening program to be effective, the failure modes should be identified. Failure analysis provides an effective method for identifying failure modes and thus aids in choosing the proper screen. Author

Review: The discussion of failure analysis of silicon devices presented in this paper is limited and superficial when compared with the authoritative and exhaustive description published by others (see, for example, the report covered by R70-14995). It does have the advantage of being prepared by a third party not interested in the manufacturer-user duel; the author is a member of neither group. One significant conclusion contained in the paper is that "approximately 80% of the defective field devices investigated are a result of induced failures caused by overstress." Thus the bulk of the silicon device failure problem, in the judgment of the author, seems to lie with the user--he uses them improperly. Most of the paper, however, discusses manufacturing problems and the various analytic steps that can be taken to isolate specific failures. This discussion contains standard observations outlined sketchily. The figures illustrating the various failures are of low quality, both in content and in photographic technique. The discussion failure analysis of semiconductor components. The significance and importance of failure analysis as a tool for determining semiconductor screens is stressed throughout the paper from the title and abstract through to the conclusion, but somehow this relationship never gets developed beyond the relatively obvious statement that proper screens are based on knowing what causes failure. The paper is not suited for specialists in semiconductor quality control or failure analysis groups; its appeal is limited to novices.

R70-15200 ASQC 844

EMPIRICAL STRESS AMPLITUDE DISTRIBUTIONS FOR CALCULATING CUMULATIVE DAMAGE

S. S. Dmitrichenko *Russian Engineering Journal*, vol. 49, no. 5 1969 p 8–10 refs

(A70-25844)

Calculation of the life of components by summation of the cumulative damage using theoretical determinations of the stress amplitude distributions obtained by a statistical analysis. It is found that when calculating cumulative damage the replacement of empirical stress amplitude distributions by theoretical distributions complicates the calculations and does not increase their accuracy. When determining the cumulative damage it is convenient to use the algorithms independent of hypotheses of the type of distribution. I.A.A.

Review: Trying to calculate cumulative damage in fatigue

or elsewhere is still an unsolved problem. In this note, the author points out that trying to fit empirical stress-amplitude distributions to some customary analytic distribution is not worthwhile. The various integrations will have to be done numerically anyway, and one might just as well use the empirical stress-amplitude distribution as the analytic one. Perhaps this will even save time on the calculations and certainly come out well within any reasonable accuracy. The author considers cumulative damage from the standard S-N curve rather than using random fatigue curves. The trend these days when using cumulative damage formulas with empirical distributions is to use not the standard S-N curve but to take curves varying in appropriate parameters for some random fatigue process and thus come much closer to the desired situation in the test.

R70-15211 ASQC 844
NOISE SPECTRAL DENSITY AS A DIAGNOSTIC TOOL FOR RELIABILITY OF P-N JUNCTIONS
Y. D. Kim (U.S. Naval Ammunition Depot, Crane, Ind.) and R. P. Misra (Newark College of Engineering, Dept. of Electrical Engineering, Newark, N.J.) IEEE *Transactions on Reliability*, vol. R-18, no. 4 Nov. 1969 p 197–200 18 refs
Contract N00164-68-M-0063

Whether noise spectral density can be used to estimate the reliability of individual p-n junctions is determined by investigation of degradation of the reverse leakage characteristic for a given period. Low frequency noise voltage spectral density observed in a p-n junction under the avalanche condition shows in two patterns: S_V(1 kHz) increases, reaches a peak, and decreases as breakdown current increases which is due to carrier multiplication and transition of the junction impedance; and a multipeak phenomenon exists which is attributed to built-in instability mechanism at the junction. The results of life tests show higher correlation between units that have multipeaks and degradation. Author

Review: This short note gives some experimental results in which the authors are obviously hoping that the kinds of noise measured in an individual semiconductor device will be an indicator of its useful life. The results are a contribution to the physics-of-failure approach for semiconductors. The correlations are rather low so there is further work to do in this field. The authors suggest that a further paper will provide a theoretical discussion of the results. The paper is of little design value.

R70-15216 ASQC 844
FAILURE MODES IN GOLD-ALUMINUM THERMOCOMPRESSION BONDS
J. H. Anderson, Jr. (University of Rochester, Dept. of Chemical Engineering, Rochester, N.Y.) and William P. Cox (Lockheed Missiles and Space Co., Palo Alto, Calif.) IEEE *Transactions on Reliability*, vol. R-18, no. 4 Nov. 1969 p 206–207 4 refs

Electrical opens and mechanical fracture have been reported as two distinct failure modes in gold-aluminum thermocompression ball bonds. It is found that the thickness of the aluminum film to which the gold wires are bonded and the temperature at which the bonds are held during aging determine which failure mode will be observed. The electrical failure mode predominates when bonds made to aluminum films 5000Å or more in thickness are aged at temperatures above 200°C but at 200°C both failure modes are observed. Mechanical fracture is expected to be the dominant failure mode when ball bonds to these 5000–10,000-Å films are aged at temperatures below 200°C. Bonds to thinner aluminum films (500–3000Å) exhibited only the electrical failure mode. Author

Review: This paper deals with physics-of-failure. It provides useful information on gold-aluminum thermocompression bonds, their failure modes and mechanisms. Those who manufacture and design the devices, as well as failure analysts, will find the material of value. The apparent activation energies are quite approximate since there is considerable scatter in the data and some of the lines, which are indicated by the data, do not appear to be straight. This kind of information is valuable to have in the literature. It appears most often only in laboratory notebooks and thus remains unknown to the rest of the profession.

85 DEMONSTRATION/MEASUREMENT

R70-15190 ASQC 851; 844
DEVELOPMENTS IN AUTOMATIC TESTING PARTS 1 AND 2
Ronald Kitchen (Marconi Co., Ltd., Central Test Equipment Research and Engineering Unit, Chelmsford, Essex, England) *Point-To-Point Telecommunications*, vol. 13, no. 4, pt. 1 Oct. 1969 p 210–218 refs and vol. 14, no. 1, pt. 2 Jan. 1970 p 15-19 2 refs

The need for automatic testing has been accentuated by the complexity of modern electronic equipment. Test philosophy and applications for autotest equipment are considered. These applications include both noncomputer and computer associated testing, the latter necessitating more complex programming of the test equipment. Emphasis is given to the importance of designing new products with facilities for automatic testing. Future trends are outlined, and the merits of automatic testing are discussed in terms of quality and cost. Author

Review: In all likelihood, there will be an increasing interest in automatic testing due to the sheer growth in the number and complexity of electronic systems. The purpose of this introductory paper is to present a broad view of some of the more qualitative aspects of automatic testing. The message is somewhat superficial because it is directed toward managers. The reader interested in fault testing techniques, detailed technical discussions of automatic testing equipment, etc. will find this paper of little value. Because of its general nature, the paper will, however, give the reader an insight into the impact of automatic testing. (It is not necessary to read Part I before reading Part II.)

86 FIELD/CONSUMER ACTIVITY

No abstracts in this issue.

87 MAINTAINABILITY

R70-15172 ASQC 873
Bell Telephone Labs., Inc., Naperville, Ill.
DESIGN PRINCIPLES FOR PROCESSOR MAINTAINABILITY IN REAL TIME SYSTEMS

H. Y. Chang and J. M. Scanlon [1969] 37 p refs

Several design principles in planning a processor organization, and in designing logic circuits and diagnostic and fault detection tests to achieve a high degree of processor maintainability in real-time systems are described. The significance of modularization, accessibility and observability, system recovery and unwinding mechanisms, and interfacing techniques for fault isolation in planning a processor organization is discussed. The importance of a thorough understanding of circuit failure-modes, eliminating circuit redundancy, and incorporating a packaging scheme which provides good diagnostic resolution is pointed out. Finally, recommendations for designing maintenance tests, deriving test results, and organizing diagnostic programs are also presented. Author

Review: The objective of this paper is to give insight into the considerations necessary for the design of a highly maintainable processor; the authors are commended for their enlightening presentation. The many pointers and recommendations concerning maintainable system design make the paper exceedingly practical. The discussion on processor organization to facilitate maintenance is particularly good. The primary purpose that this paper serves is to unify several aspects of system maintainability in a manner which reveals the interrelations between such factors as circuit design, processor organization, fault detection and diagnosis techniques, and their importance to the overall system design. The authors also point out several areas where additional research is needed. The paper results in useful guidelines which can be of value to both the newcomer and the experienced engineer engaged in the design of highly maintainable digital systems. (Three typographical errors as well as a discontinuity in the text were noted in the copy of the paper available to the reviewer.)

R70-15176 ASQC 871; 813

National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, Ala.

MAINTAINABILITY/SUPPORT REQUIREMENTS FOR SPACE PROGRAMS

Ward H. Cook and Chester B. May Jul. 1969 25 p refs

(N69-38665; NASA-TM-X-53855) Avail: CFSTI

Presented is an approach for identification and development of maintainability/support requirements that permits progression from state-of-the-art techniques and equipment to future requirements through use of standard engineering procedures. This approach includes an analysis of future program requirements to identify probable support requirements with an inductive reasoning approach to bootstrapping them from state-of-the-art techniques and equipment, since the identification alone of a support requirement is not enough. It is also shown how to achieve the objectives. Author

Review: It is readily recognized that manned space travel involving months and years of mission time, rather than days or weeks as at present, will create severe demands on maintainability and support. This narrative report outlines and discusses the problem. Even though quantitative data are not given, persons concerned with equipment design and maintainability/support for missions of such long duration will find the report helpful in identifying the many aspects of the problem. Whereas the solution of the difficulties will no doubt borrow from many of the techniques developed for military systems and missions, the author is certainly correct in recognizing that the in-space maintainability and support problem is quite different from that experienced by the military. A "bootstrap" or learning approach will be required. The sixteen references and bibliographies which are listed will be helpful.

R70-15177 ASQC 871

Weather Bureau, Silver Spring, Md. Engineering Div.

MANPOWER STANDARDS FOR MAINTENANCE OF ELECTRONIC EQUIPMENT (1969)

Russell L. Hovey Aug. 1969 27 p

(N70-22345; PB-188038; ESSA-TM-WBTM-ENG-1) Avail: CFSTI

The equipment maintenance reporting system (EMRS) is used to monitor, analyze, and refine the manpower standards for Weather Bureau electronics technicians. The use of EMRS produces manning standards which constantly are responsive to the needs of the equipment and the Bureau. USGRDR

Review: While the procedures described in this report are not a designer's tool, they are appropriate for improving the maintenance of existing installations which must operate continuously. They could readily be used, for example, for optimizing routine repair procedures of spacecraft tracking networks. Even though the analytic procedures are technically competent, the discussion in Section 3.3 is not clear. For example, it is not readily apparent precisely what is being correlated with what, what specific relation the graphs have to the correlation, and what criteria are being used for optimization. The experienced analyst, however, can readily grasp the gist of the general approach, decide for his system what correlations are needed, and determine what criteria to use for optimizing repair schedules. With the above exception, the report is well written and will interest anyone concerned with improving repair procedures of existing systems. In connection with Section 3.3, the author in a private communication has commented as follows: "...we have found that the variables to be correlated and the degree of correlation will vary widely with the equipment being analyzed. It is the general approach which I consider most important and I feel it can be used to advantage with any operational system to help in optimization of the manpower assigned to individual instruments."

R70-15203 ASQC 872; 821

A TIME DEPENDENT COMPLEX SYSTEM WITH PREEMPTIVE PRIORITY REPAIRS

Santosh Kumar (Royal Melbourne Institute of Technology, Dept. of Mathematics, Melbourne, Vic., Australia) Naunihal Singh (Monash University, Depty. of Mathematics, Clayton, Vic., Australia)

IEEE *Transactions on Reliability,* vol. R-18, no. 4 Nov. 1969 p 163–164 8 refs

A repair system is analyzed that has three kinds of components, each with a different repair priority. Type 1 is essential to system operations and has the highest priority of repair; there is only one such component. Type 2 is nonessential (its failure degrades the system) and has an intermediate priority of repair. Type 3 is similar to type 2 except that it has the lowest priority of repair. There are many types 2 and 3 components. The differential equations for system state probabilities are solved by Laplace transforms, but only in implicit form. Author

Review: This is one of the many papers appearing in the literature which analyze a very particular scheme for repairing systems. The mathematics is quite compact but appears to be straightforward. The general solution is intractable according to the authors, but it can be evaluated for particular cases. The utility of this kind of exercise would be greatly enhanced if there were some method of keeping track of them all so that when presented with a problem one could search through a reference list and find out if and where it had been solved. The paper will not be of value directly to design and reliability engineers unless they happen to recognize one of their problems as fitting this model. Those doing research in the

field may be interested in the method of solution (although it is fairly straightforward) and may also wish to see how the cases considered here fit into the general pattern of solved problems.

R70-15212 ASQC 872
ON-LINE OPTIMIZATION OF MAINTENANCE AND VERIFICATION SCHEDULES
William S. Meisel (University of Southern California, Dept. of Electrical Engineering, Los Angeles, Calif.) IEEE *Transactions on Reliability,* vol. R-18, no. 4 Nov. 1969 p 200–201 2 refs
Grant NGR-05-018-044
(A70-28013)

Description of method for determining a verification or maintenance schedule that is neither needlessly frequent nor dangerously infrequent for the safety of a complex system it is to ensure. The described method uses the system itself to derive the maintenance schedule that yields a given mean time between failures. The method does not require calculation of the mean time between failures, but allows adaptive convergence to the desired result. Convergence is guaranteed for reasonable assumptions. IAA

Review: This is one of those helpful little techniques that one is not likely to learn in school nor is it grandiouse enough for a paper at a conference, but it is helpful to know. The note is extremely short and easy to read; the mathematics is correct. Readers will find it helpful to remember where they read it. One should, or course, carefully note the restrictions in the theory, they are important and well stated.

88 AVAILABILITY

R70-15202 ASQC 882; 824; 412
LOWER CONFIDENCE LIMITS FOR AVAILABILITY ASSUMING LOGNORMALLY DISTRIBUTED REPAIR TIMES
Henry L. Gray (Texas Technological College, Lubbock, Tex.) and William R. Schucany (Southern Methodist University, Dallas , Tex.) IEEE *Transactions on Reliability,* vol. R-18, no. 4 Nov. 1969 p 157–162 5 refs
Grant ONR N00014-68-A-0515

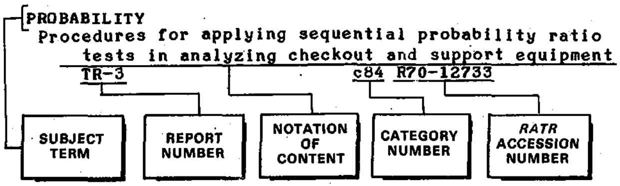
Exact lower confidence limits are established for the availability ratio A where $A = \mu_Y(\mu_Y + \mu_X)$ and μ_Y is the mean time between failures and μ is the mean time to repair. It is assumed that the time between failures has an exponential distribution while the time to repair is lognormally distributed, with known variance. A test of the hypothesis $A = A_0$ is also developed and power curves are included. Some results on the comparison of confidence intervals when the time to repair is assumed to be exponentially distributed are given. Author

Review: This paper presents the theory for--and several curves giving the results of--the lower confidence limit calculation with exponential failure times and lognormal repair times. This paper will be of value to those statisticians who are assisting reliability engineers in this kind of calculation. Besides giving the results, they are related to earlier results; and the alleged conservatism of the exponential assumption for repair times is analyzed and shown to be inaccurate. The authors indicate that under some circumstances, one may wish to calculate his own curves. To do so will require some statistical and programming sophistication on the part of the user since those techniques are not spelled out in the paper. It is not obvious for many of the curves how robust they are to the assumption of lognormality of repair times. One occasionally is rather concerned about the influence of the tail region (wherein data are sparse) on the overall values obtained.

SUBJECT INDEX

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS VOLUME 10 NUMBER 8

Typical Subject Index Listing



The Notation of Content, rather than the title, is used to provide a more exact description of the subject matter. The category number and *RATR* accession number are used to locate the abstract-review appearing in the abstract section of *RATR*.

A

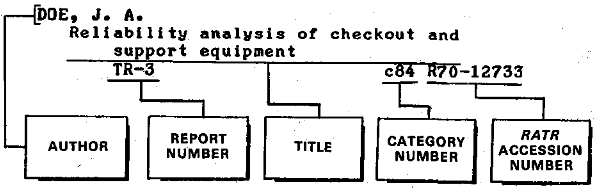
B

C

PERSONAL AUTHOR INDEX

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS VOLUME 10 NUMBER 8

Typical Personal Author Index Listing



The category number and the *RATR* accession number are used to locate the abstract-review appearing in the abstract section of *RATR*.

REPORT AND CODE INDEX

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS VOLUME 10 NUMBER 8

List of Report Numbers

This may be used to identify the *RATR* accession number of reports covered in this journal. To the right of each report number is the *RATR* accession number preceded by the category number for locating the abstract-review in the abstract section of *RATR*. For purposes of this index, AD, N, and A numbers (accession numbers from *TAB, STAR,* and *IAA,* respectively) and ASQC code numbers are treated as "report" numbers. Thus, the section of this index listing ASQC codes may be used to identify the *RATR* accession number of the coded abstract-reviews appearing in *RATR*.

ACCESSION NUMBER INDEX

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS VOLUME 10 NUMBER 8

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This list of *RATR* accession numbers may be used to identify the category in which a numbered abstract-review appears in the abstract section of this journal. Accession numbers are arranged in ascending order. Preceding each accession number is the category number for locating the abstract-review in the abstract section of *RATR*.

Reliability Abstracts and Technical Reviews

SEPTEMBER 1970

Volume 10
Number 9

R70-15217—R70-15279

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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The second section of *RATR* contains four indexes: The Subject Index is to assist in scanning or searching the literature on specific topics. The Personal Author Index identifies the publications of specific authors. The Report and Code Index is a listing of the report numbers of items abstracted and reviewed in the journal; this index also includes a listing of the ASQC codes for identifying the *RATR* accession numbers of the items to which the codes have been assigned. The Accession Number Index identifies the categories in which the abstract-reviews appear in the journal. Cumulative indexes are published annually.

EXAMPLES OF CITATIONS IN *RATR*

***RATR* ACCESSION NUMBER**	R70-12733 ASQC 844; 413	**ASQC CODES**
	General Equipment Company, Banville, Calif.	**CORPORATE SOURCE**
TITLE	**RELIABILITY ANALYSIS OF CHECKOUT AND SUPPORT EQUIPMENT**	
AUTHOR	John A. Doe 23 Sep. 1969 27 p refs	**PUBLICATION DATE**
CONTRACT OR GRANT	(Contract NAS15-13411)	***TAB* AND *STAR* ACCESSION NUMBERS**
REPORT NUMBER	(AD-629305; N69-15098; TR-3) Avail: CFSTI	**SALES AGENCY AND PRICE**

***RATR* ACCESSION NUMBER**	R70-12739 ASQC 814	**ASQC CODE**
TITLE	**SEMICONDUCTOR RELIABILITY**	
	Joseph A. Smith (Eastern University, Arlington, Penn.)	**AUTHOR AND AFFILIATION**
JOURNAL REFERENCE	*Electric Journal,* vol. 8, Apr. 1969, p 478–492.	
	(A69-12569)	***IAA* ACCESSION NUMBER**

***RATR* ACCESSION NUMBER**	R70-12765 ASQC 773; 221; 823	**ASQC CODES**
TITLE	**TESTS OF SYSTEMS WITH SOME DEPENDENT FAILURES**	
	Joseph A. Smith (Eastern University, Arlington, Penn.) and B. James White (General Equipment Company, Banville, Calif.)	**AUTHORS AND AFFILIATIONS**
CONFERENCE OR SYMPOSIUM REFERENCE	*Association of Reliability Engineering, Failure Rate Conference, Olney, Tex., Mar. 13–17, 1969,* 8 p. Available from Assoc. of Reliability Eng., New York: $1.00	**AVAILABILITY AND PRICE**
***IAA* ACCESSION NUMBER**	(A69-12407)	

OLUME 10 NUMBER 9

Reliability Abstracts and Technical Reviews

A Monthly Publication

of the National Aeronautics and Space Administration

September 1970

80 RELIABILITY

No abstracts in this issue.

81 MANAGEMENT OF RELIABILITY FUNCTION

R70-15226 ASQC 815

SPECIFYING RELIABILITY

A. W. H. Smith (Mallory Capacitor Co., Indianapolis, Ind.) *International Electronics Conference, Toronto, Jun. 10, 1969 Paper* 2 p

Definitions of electronic component reliability are examined with reference to the Military Established Reliability specifications. The design of these specifications for tantalum electrolytic capacitors is reviewed in terms of the needs they are intended to satisfy. Some alternative tests for reliability and their underlying principles are proposed. Author

Review: Specifications and standards are usually written with specific application(s) in mind and rarely do they cover all situations. This is perhaps as true for Established Reliability (ER) specifications as for their forerunners. An underlying, and very worthwhile, message in this brief article is: specifications and standards can effectively serve as guidelines but be sure tests are tailored to meet the specific needs at hand rather than the provisions of a blanket specification. This can be very appropriate, for example, when using specifications motivated by military needs for aerospace applications. The cases cited for relevancy of MIL-STD-690 and MIL-STD-790 to certain applications of tantalum capacitors illustrate the point well. Some readers will no doubt be interested in the author's comments on how the viewpoints of various members of the design and production organization influence the test decisions.

R70-15229 ASQC 812; 871

Air Force Systems Command, Wright-Patterson AFB, Ohio. Human Resources Lab.

A SYSTEMS APPROACH TO ELECTRONICS MAINTENANCE TRAINING

Horace H. Valverde 1969 17 p refs Presented at the IEEE and ERS Intern. Symp. on Man-Machine Systems, Cambridge, Engl., 8-12 Sep. 1969

(N70-24139; AD-698752) Avail: CFSTI

The document describes the development and evaluation of an Air Force systems-oriented electronics maintenance course for weapon control systems technicians. The program consisted of three phases: A behavioral description based upon a task analysis of actual job requirements. An experimental 14-week training course prepared from the objectives obtained in Phase 1. A group of subjects with electronics aptitude percentile scores ranging from 60 to 95 received training. Data on all subjects was obtained including aptitude scores, reading ability scores, course grades, end-of-course performance testing, field followup performance testing and supervisory appraisals. The performance of experimental and control groups was compared on the basis of these data. Author (TAB)

Review: The training of technicians is an important factor in system maintenance. This, along with the high cost of training and low reenlistment rates, has prompted the armed forces to explore new training methods. The purpose of this paper is to describe a program in which a "systems approach" was employed to increase the efficiency of maintenance training. The author presents the material clearly and his treatment is adequate. Although he is concerned with training personnel for electronic maintenance of a weapon control system, this paper will be worthwhile to those persons involved with other types of job-related training where the emphasis is upon performance rather than theory.

R70-15237 ASQC 810; 844

PREVENTION OF POWER FAILURES IN MAJOR NETWORKS

Orest A. Meykar (U.S. Naval Ship Systems Command, Washington, D.C.) (IEEE *Seminar of the Mexico Section, 5th, Oct. 1969.)* IEEE *Transactions on Aerospace and Electronic Systems*, vol. AES-6, no. 2 Mar. 1970 p 119-128 7 refs

An outline of the philosophy underlying the Federal Power Commission's study of the reliability of electric power systems and their distribution networks is presented. A broad review of bulk power system reliability is given. The steps required for the prevention of major power outages of wide extent and substantial duration are set forth. Author

Review: This paper is oriented toward the manager and non-power expert in that it avoids as much jargon as possible and

tutorially introduces each of the topics, thus requiring a minimum of expertise in any of them. By its very nature, it is quite general; it does not go into specific pieces of equipment but rather talks about the kinds of details to which one must pay attention and illustrates how one should pay attention to them. Since large portions of the aerospace industry and launching complexes are dependent on electrical power, the considerations in the article are of direct concern. But more important to the reliability engineer is a review of the techniques being used in power systems to achieve high reliability. Power systems are extremely complex collections of many different kinds of equipment, many of whose characteristics are not known in enough detail and, if they were, the equations would get too complicated to use all of the detail. Aerospace engineers have a similar problem in analyzing many of the complicated aerospace systems. A great deal of emphasis must be placed on interfaces of subsystems so that the subsystem can be analyzed by itself, and so that the interfaces are not too complicated to defy analysis. This paper is a digest of the report to the Federal Power Commission by the Advisory Committee on Reliability of Electric Bulk Power Supply, dated June 1967. The full report is available from the U.S. Government Printing Office, Washington, D.C.

R70-15238 ASQC 810
MANAGEMENT'S VIEW OF RELIABILITY
Harold G. Warner (General Motors Corp., Operations Staff, Detroit, Mich.) (IEEE *Industry and General Applications Group, Annual Meeting, Detroit, Oct. 12-16, 1969.)* IEEE *Transactions on Industry and General Applications*, vol. IGA-5, no. 6, Nov./Dec. 1969 p 654-656

Management considerations related to product reliability are discussed. It is pointed out that higher standards of performance and value demanded by the customer have prompted a greater emphasis by management on reliability from design to manufacturing to delivery. The establishment of a sound reliability program and how factors such as design, production, quality control, human factors, and economics can affect it are presented. A.L.

Review: This is a paper written by management for management. Reliability in the aerospace or any other industry will get only as far as management wishes to put it. Thus, papers such as this, which are written by successful management and directed towards others in the same field, are more likely to be well received, and consequently acted upon, than are exhortations from quality and reliability engineers. The author gives examples of the kinds of detail to which one must pay attention. He points out that they do not confine themselves to narrow fields such as electrical or mechanical or hydraulic, but that they usually cross these lines many times. Thus, the ordinary engineer, whether he be in design, production, maintenance, or plant, must have a broad enough background to recognize where he needs help and to know whom to ask for it. As the author points out, his examples are very common and down to earth; nothing esoteric or sophisticated was required to solve them. Often the thing that causes poor reliability is these details' being lost in the shuffle. The kinds of reliability problems that can be attacked by equations are usually well under control. It is the type of reliability problem associated with people to which this article is directed and which still eludes us more often than it should.

R70-15239 ASQC 815
BOB PEASE OF PHILBRICK/NEXUS SPEAKS OUT ON WHAT'S WRONG WITH MIL-STD-883
Robert A. Pease (Philbrick/Nexus, Boston, Mass.) IEEE, vol. 18, no. 1 Jan. 1970 p 42-47

The author expresses his personal opinion as to the adequacy of the test procedures specified in MIL-STD-883 for the testing of linear integrated circuits. An alternative method is recommended. A.L.

Review: Bob Pease doesn't like MIL-STD-883 and in this short paper he tells why—and how. As summed up in a subsequent private communication: "the key weakness of MIL-STD-883 is that it's so bad that nobody uses it." Virtually all his criticism is directed toward the electrical testing of linear integrated circuits specified in the standard (methods 4001 through 4007). Several parts of the standard, viz., (1) the earlier sections on digital integrated circuits, (2) those on workmanship, and (3) those on mechanical and environmental testing, are declared tolerable and dismissed after a few words of praise plus some minor criticisms. The linear IC test methods, however, ". . . 'are cumbersome, time-consuming and are not adaptable to automatic test techniques' . . ." (quoting a quote in the paper). These methods are directly attributed (by the author) to the influence of two anonymous engineers who designed a linear IC tester while employed by a major aerospace company, then formed their own company to manufacture and sell this tester, and in the process succeeded in selling their approach to the military authors of MIL-STD-883. This bit of drama is presented (by the author) by way of explaining the ". . . narrow background and provincial viewpoint . . ." reflected in the linear test circuits of 883. Among the specific objections raised by Pease are: (1) the use of capacitively coupled ac signals for gain measurements (testing is therefore "hopelessly slow and completely impractical" [quote from subsequent private communication]), (2) omission of a specified load resistor for measurement of voltage gain and full output–voltage swing, (3) the use of the differential voltage gain to define common mode rejection ratio and power supply rejection ratio. In addition, Pease notes the omission of what he considers key definitions and stability requirements. He cites his own company's superior approach to the same testing problems, although acknowledges that his company's solution is not the universal standard that 883 attempted to be. There is nothing subtle about the paper in its attack on the linear IC test portion of 883. In his indignation, the author sees mischief and incompetence where others may not. For example, 4003.1.1.2 of MIL-STD-883 defines common mode rejection ratio (CM rr) as the ratio of differential open loop gain, A_d, to the common mode voltage gain, A_c: $CMrr = A_d/A_c$. The standard then notes that CMrr is usually expressed in decibels: $CMrr = 20 \text{ Log } (A_d/A_c)$. The author sees these two differing expressions for CMrr as a "lovely contradiction." Such stretching to criticize with exaggeration weakens the paper's impact, convincing the reader more of the author's unhappiness with the standard than of the merit of his criticism. Most readers will probably not "take his word for it," as the author guesses but will want to hear other opinions. The author's style is direct, blunt and dramatic—designed to capture attention. It lends itself to overplaying the attack, causing the reader to suspect that occasionally the technical argument gets subordinated to showmanship. This shortcoming notwithstanding, or perhaps because of it, the paper is highly readable—action-packed from start to finish.

R70-15240 ASQC 810
PACKAGING AND PRESERVATION
C. H. Bray (Ministry of Defence, I.F.V.M.E. (Packaging), London, England) *In: The Quality Engineer, National Inspection and Quality Engineering Conference, Issue, 9th, Oxford, Sep. 22-25, 1969* London The Institution of Engineering Inspection Nov./Dec. 1969 p 25-30

The importance of packaging and preservation to ensure that the finished product reaches the customer in acceptable condition is discussed. It should be considered an integral part of the overall manufacturing process. Various physical, chemical, and atmospheric hazards are discussed along with preservation materials available for use with various types of products. The importance of packaging design and cushioning materials used to protect against physical hazards are enumerated, and examples of the application of various types are given. A.L.

Review: This topic is one not often included in the reliability engineer's repertoire, but it is, of course, essential to the reliable functioning of any product. Customers, whether in aerospace, defense, consumer, or industrial areas, are not likely to be happy with the reliability of any product that arrives in a non-working condition. For some products, the transportation environment is probably the worst one they will ever see. This paper not only explains the kinds of details to which one must pay attention, but also goes on to explain how and why. As with so many other kinds of information, it would be easy to pass it off with, "oh, everyone knows that." Outside of the fact that everyone does not know it, a great many people do not apply it even when they do know it. This paper is virtually in the form of a checklist which makes it even easier to use. It is commended to the attention of production and reliability engineers.

R70-15246 ASQC 813; 340
THE QUALITY SURVEY IN AN R AND D QUALITY PROGRAM
Joseph N. Faillace (Western Electric Co., Inc., Quality Assurance, Cockeysville, Md.) *In: American Society for Quality Control, Annual Technical Conference, Transactions, 24th, Pittsburgh, May 11-13, 1970* Milwaukee American Society for Quality Control, Inc. 1970 p 145-152 1 ref.
(A70-31106) Avail: $13.00

Examination of the performance of quality evaluation surveys at contractors, primarily those that are contractually obligated to implement a quality program. The planning and accomplishing of the quality survey activity is described taking into consideration: (1) formation of the survey committee, (2) preparation of the survey, (3) performance of the survey, (4) review and report, and (5) follow-up. IAA

Review: Quality or vendor surveys are a topic on which considerable controversy exists. Perhaps the reason for this is that surveys are often made, but the range of thoroughness with which they can be made is so great and the standards for their effectiveness are so hazy and unenforceable that many people have had excellent experience with them while others have had extremely poor experience. This author is implicitly in favor of them and is showing how to conduct them effectively. (Another paper given at the same conference and found on pp. 167-170 in the Transactions discusses specifically the training of personnel for this task.) The recommendations will be of most benefit to those who are trying to set up a program rather than to those who have been doing it for some time. The directions given are good although not necessarily complete. It is most important to remember that one can perfunctorily go through the motions and come out with an extremely poor review, and it may not be immediately obvious to the supervisors that a poor review has been made. This is a good paper; it emphasizes worthwhile points. The illustrations of specific defects which were found in the system are of special value to beginners for whom the earlier generalities may have been too vague.

R70-15249 ASQC 812; 323; 345; 816
TRAINING THE SUPPLIER QUALITY EVALUATOR
La Vern M. Johnson (Naval Fleet Missile Systems, Anti-Submarine Warfare Task Office, Analysis and Evaluation Group, Corona, Calif.) *In: American Society for Quality Control, Annual Technical Conference, Transactions, 24th, Pittsburgh, May 11-13, 1970* Milwaukee American Society for Quality Control, Inc. 1970 p 167-170 Avail: $13.00

Lack of management awareness, improper selection of individuals, and inadequate training are cited as the main reasons why the estimated 70 to 80 percent of personnel are not qualified to perform comprehensive, effective, and rapid inplant audits and supplier evaluations. Some principles and techniques that should be taught are outlined, and the following points are made: (1) It is important that personnel assigned to performance of audits and evaluations be carefully selected. Qualification should be based on inherent attributes as well as education and experience. (2) The importance of comprehensive and conclusive audits and evaluations should be stressed. All aspects of the quality programs should receive adequate consideration in order to ensure efficient and effective production of an acceptable product. (3) All levels of management should be apprised of the need for adequate quality programs and the importance of audits and evaluations in assessing such programs. (4) Managers should examine individual qualifications, audits, and evaluation programs to determine whether the needs of program, product, and customer are being fulfilled. M.G.J.

Review: Vendor surveys are among the more controversial reliability activities. This paper attempts to get vendor evaluation out of that class by showing how the evaluators should be trained, the thesis being that good evaluators will produce a worthwhile evaluation. The ideas are good; those engaged in quality surveys should be familiar with the contents of the paper. One possibly controversial aspect of this recommendation is that the evaluator *need not have technical expertise* in the hardware being manufactured. If he does not have such expertise, he certainly will require an even higher level of training in his evaluation job in order to overcome this deficiency. In a private communication, the author has stated that the important consideration as far as "not needing to have an expertise in the hardware" is, it is considerably more costly and difficult to adequately train all technical types in the methods are techniques of evaluation performance. However, well-trained evaluators who have a general knowledge of the hardware can route out the problems. In "hardware" type evaluations it is desirable to have technical types involved. The author has also published a book on this topic.

R70-15250 ASQC 814; 353
REDUCING MANUFACTURING COSTS WHILE MAINTAINING RELIABILITY AND QUALITY
T. J. Cartin (Bendix Corp., Communications Div., Baltimore, Md.) *In: American Society for Quality Control, Annual Technical Conference, Transactions, 24th, Pittsburgh, May 11-13, 1970* Milwaukee American Society for Quality Control, Inc. 1970 p 177-182 Avail: $13.00

Description of the experience in reducing the manufacturing costs while maintaining the reliability and quality of the product. The key role in the system described is played by an accurate cost reporting system combined with proper quality level reporting. As an example, the manufacturing cost and quality of a mass production product are analyzed. IAA

Review: The point of this paper is that in order to make intelligent decisions about manufacturing changes, one must have a good in-house defect reporting system. This allows one to know what part of the manufacturing process is introducing the defect and what kind of quality-effects a change in a manufacturing process will have. If this defect reporting system is not in existence, then manufacturing changes are made blindly and all too often, quality and reliability will suffer. There is little, if anything, to argue about in this paper. The points are good ones. Apparently the idea of knowing what is going on in the manufacturing process is one that must be repeated time and time again.

R70-15251 ASQC 813

WHEN DOES QUALITY BECOME RELIABILITY?

J. Douglas Ekings (Xerox Corp., Rwiability Engineering, Rochester, N. Y.) *In: American Society for Quality Control, Annual Technical Conference, Transactions, 24th, Pittsburgh, May 11–13, 1970* p 183-193 Milwaukee American Society for Quality Control, Inc. 1970 Avail: $13.00

(A70-31109)

Description of the quality control of a complex electronics equipment using new technical and management approach for attaining the specified reliability. It is stated that the reliability program must provide direction to all major functions of the business cycle. Use of quantitative data is required to assess the results of these efforts. The assessments, to be effective, must be of a simple and direct form, readily comprehended by production personnel, middle management, and top management. IAA

Review: This paper is the same as the one covered by R70-15103.

R70-15252 ASQC 810; 760

QUALITY IMPROVEMENT BY ELIMINATION OF THE TRADITIONAL INSPECTION DEPARTMENT

R. J. W. Tucker (Northern Electric Co. Ltd., Quality Engineering, Bramalea, Ontario) *In: American Society for Quality Control, Annual Technical Conference, Transactions, 24th, Pittsburgh, May 11–13, 1970* Milwaukee American Society for Quality Control, Inc. 1970 p 237-242 Avail: $13.00

The problems inherent in the search for lower cost and higher quality are reviewed, and the reasons which led to the reorganization of the quality control function are discussed. It was decided that the production departments had to be totally responsible for quality, and that there was a need to better define responsibility by making each department as completely responsible as possible. The techniques used to overcome personnel resistance to change are described. As a result of this integrated system, it was found that, along with quality improvement, gains were made in other areas of cost and schedules, and that the morale of the production operators and supervisors was greatly improved.

Review: This paper has an interesting thesis, but it is one about which people are often noncommittal. The thesis seems at variance with the way in which many companies are actually run, at least those in which the inspection group is not under manufacturing. The author's idea is not to separate authority and responsibility, but to keep them in the same place, as is good management practice. Therefore, those with a control over the manufacturing process should be responsible for it, and inspectors should be part of that group. The quality group then performs an auditing function and a staff function of providing expertise in the quality area for manufacturing. Certainly, when the thesis is baldly presented, it is almost impossible to argue with it. Most of the nonbelievers essentially talk their way around it in an amorphous fashion. The idea also seems to run counter to total quality engineering (and perhaps well it should) since too often the idea of total quality engineering means that the quality department should take over every function in the plant from management on down. It would be most worthwhile to have this idea debated thoroughly in the literature rather than having it arise only from time to time in a technical conference or local section speech. It seems to be a good idea, yet one which many quality-control and reliability engineers and managers find objectionable.

R70-15255 ASQC 815; 841; 850; 860

REVOLUTION IN WARRANTIES

Richard M. Jacobs (Newark College of Engineering, Dept. of Industrial Engineering, Newark, N. J.) *In: American Society for Quality Control, Annual Technical Conference, Transactions, 24th, Pittsburgh, May 11–13, 1970* Milwaukee American Society for Quality Control, Inc. 1970 p 341-344 5 refs Avail: $13.00

Current warranty practices and consumer dissatisfaction are discussed, and the problems involved in matching actual usage rates to the warranty period are examined. The value of elapsed time indicators is assessed, and several examples are given to the use of a small, fail-safe, inexpensive electrochemical elapsed time indicator. It is concluded that as additional experience mounts in the use of these devices, manufacturers will be able to economically increase warranty time, again providing an impetus to sales volume and profits. M.G.J.

Review: The revolution mentioned in the title appears to be that a simple calendar-time guarantee is not appropriate for many consumers and for many manufacturers. The author then recommends an inexpensive elapsed-time indicator that can be used in the product and suggests essentially that the guarantee be limited by elapsed-use-time as well as elapsed-calendar-time. Those who have yet not considered this point and its potential value should become familiar with it; those who have will find little new to them in the paper.

R70-15261 ASQC 815; 221

OPERATING CHARACTERISTICS OF MIL-STD-105D SWITCHING PROCEDURES

John S. White (University of Minnesota, Industrial Engineering - Operations Research Div., Minneapolis, Minn.) *In: American Society for Quality Control, Annual Technical Conference, Transactions, 24th, Pittsburgh, May 11–13, 1970* Milwaukee American Society for Quality Control, Inc. 1970 p 401-408 2 refs Avail: $13.00

An integral part of the MIL-STD-105D sampling procedures is the provision for three degrees of severity of sampling inspection: normal, tightened, and reduced inspection. Explicit expressions for the operating characteristics of tightened and reduced inspection are derived. Numerical results are given for a selected set of AQLs. Author

Review: This is a most interesting and useful analysis of MIL-STD-105D. It contributes to a better understanding of reduced and tightened inspections and their consequences. Such an analysis is, or course, sensitive to the assumptions being made (in particular, the very standard, usual assumption made in the classical statistical analysis that one is completely ignorant of

the quality of a lot except for the sample which was taken).The tightened and reduced inspections are, of course, an attempt to bypass this restriction in classical analysis; namely, when one is under tightened inspection, one is presuming that the chance of a lot's being poor is better than it used to be. Likewise, when one is on reduced inspection, one has some engineering confidence that the lots are likely to be better. Thus, it would be interesting to see what kind of a Bayesian prior distribution would give the same kinds of testing assumption as the ones specified in MIL-STD-105D. This is not to say that the present analysis is not worthwhile; it is most useful. It is just that the kinds of answers one gets depend on the assumptions one makes, and there is no unique set of assumptions in a situation like this. Another possibility for analysis is to assume that reduced inspection means that lots are being cumulated, an analogy to a cumulative sum chart. One thing this paper does help show is that there are no clear-cut explicitly-stated statistically-tractable assumptions on which the transitions from one kind of sampling to another are based. This is certainly a potential area for future improvement of the plans, and analyses such as this present one serve admirably to show the need for such reexamination and to assist in it.

R70-15263 ASQC 813; 345
TOTAL QUALITY CONTROL: A PROGRAM OF APPRAISING RESPONSIBILITIES

Sidney L. Emmons (North Electric Co., Quality Assurance, Galion, Ohio) *In: American Society for Quality Control, Annual Technical Conference, Transactions, 24th, Pittsburgh, May 11–13, 1970* Milwaukee American Society for Quality Control, inc. 1970 p 425-428 Avail: $13.00

The quality assurance (QA) or appraisal system described provides all levels of management with a measure of their success, in addition to providing operational procedures, policies, and acceptance levels to all inspection functions. The application of specifications, procedures, and policies are controlled by the individual company divisions with the audit function serving as a tool to insure compliance to in-process procedures and to measure their relative success in producing the end result. The audit system consists periodic in-process and random end-item evaluations; it does not supplement normal acceptance methods such as inspection, test, and laboratory life testing. Means of reporting the data are also discussed. Author

Review: Articles on how to organize a quality control effort and on total quality control are legion. Total quality control is not a well defined term as far as the literature is concerned although small groups of individuals may consider that their own group has "properly" defined the term. This paper appears to be going against some long-time trends and perhaps that long-time trend is changing. The message has appeared before; it is not new although it is fairly rare in print. The message essentially is that quality (reliability) is the responsibility of the department generating the product. Satisfactory performance is measured against the drawing or other suitable standards. The functions of the quality assurance department are then for audit and advice. These ideas, as expanded upon in the paper, have a great deal of merit and deserve serious consideration by any company which is contemplating a revision in its quality control/reliability organization. The basic premise of the system is that authority and responsibility must go hand in hand, and that to make quality control responsible for that over which it has no authority is a big mistake (not to mention ineffective). It is a pleasure to see papers such as this which try to limit the areas of authority and responsibility of the quality control department and make quality/reliability the engineering-production function that it needs to be. Since any company or orgainzation has its formal, nominal organization charts and its informal, actual organization, care must be used in distinguishing between the two. The working of the system will not always be simple and easy. For example, a department manager must have some idea of a single figure of merit desired by management, and he must possess the skills (or know where to find them) to optimize this figure of merit for his department. If there are several figures of merit for any given department, such as quality and production, then the manager does not know the tradeoffs that higher management wishes him to make, should they be necessary. The making of tradeoffs involves a single figure of merit and achieving this requires more management expertise than often exists.

R70-15264 ASQC 810; 612
CONTINUOUS SYSTEM SIMULATION FOR QUALITY CONTROL STUDIES

R. D. Brennan (IBM Corp., D. P. Div., Palo Alto, Calif.) and L. R. Sanders (AEC, Golden, Colo.) *In: American Society for Quality Control, Annual Technical Conference, Transactions, 24th, Pittsburgh, May 11–13, 1970* Milwaukee American Society for Quality Control, Inc. 1970 p 441-448 5 refs Avail: $13.00

The development of continuous system simulation languages (CSSL) is discussed, with particular emphasis given to IBM's S/360 continuous systems modeling program (CSMP). Its applicability for quality control system analysis is illustrated by a simple model of a fabrication facility, including the effect of management pressures on worker performance and the effect of a sampling control function during fabrication on scrap losses. Author

Review: This paper encourages the use of system simulation in order to show how a change in a quality control system will work. Mainly, the paper proclaims the improved facility for modeling socio-economic systems provided by the "new breed" of continuous system simulation languages developed in the last several years. The description of simulation systems is very brief. The flow chart will be of help to the uninitiated, but the programming statements will be of no value to one not familiar with the particular programming language except perhaps to show their relative simplicity once one knows the language. The author's example is simplified but they consider it not untypical in showing the reality of manufacturing life. There are two big difficulties in any simulation operation. The first is the purely mechanical one of learning the simulation language, although the language endorsed by the authors is a simple one. Getting any computer routine going is usually a traumatic and expensive procedure. The computer is an extremely valuable tool, and it is usually worth going through the trauma and expense of learning to use it. The day has not yet arrived, however, where the use of the computer is as inexpensive and easy as it is often glowingly portrayed. The second and even more fundamental problem area is the adequacy of the model. The authors touch upon this but do not dwell on it--it needs dwelling upon. All the computer can do, of course, is tell you how your *model* will respond to changes, not how your *company* will respond to those changes. Very often, when the results of the simulation seem odd, the reason is that the model contains non-obvious defects (and they need not all be of omission). Thus, managers of quality/reliability departments and higher level management can read this paper if they are not familiar with what simulation techniques can do. They should remember that the paper is designed to encourage interest in those techniques and to temper their judgments accordingly. Computer

simulation is a valuable tool but so is a buzz saw. They are both a little trickier to use than appears on the surface, and both can be dangerous.

R70-15267 ASQC 817
Sandia Corp., Albuquerque, N. Mex.
SUBSYSTEM REQUIREMENTS AND TRADEOFFS
F. W. Mueller 1969 15 p Sponsored by AEC
(N70-25342; PB-188784; SC-DC-69-2067) Avail: CFSTI

The derivation of subsystems requirements from system requirements inevitably involves mathematical modelling of the system to describe the relationships between system and subsystem characteristics. The paper discusses a rather basic approach to reliability modelling that is quite generally appropriate, and alludes to some refinements that are useful in treating certain types of systems. The interaction between reliability modelling and other mathematical models of performance characteristics is emphasized and reliability modelling is identified in terms of the broader aspects of systems analysis. USGRDR

Review: This is a rough draft of a paper which was subsequently published in the Proceedings of the 1970 Annual Symposium on Reliability and was covered by R70-15050. There are some typographical errors in this paper which have been corrected in the final draft; also the author's references, missing in this paper, are present in the final draft.

R70-15275 ASQC 810
Commission Electrotechnique Internationale, Geneva (Switzerland).
MANAGERIAL ASPECTS OF RELIABILITY [LA FIABILITE, PROBLEME DE DIRECTION]
1969 15 p in FRENCH and ENGLISH

This report, approved by 16 countries, outlines some of the many factors associated with the managerial aspects of reliability. The scope of the reliability program is discussed in terms of research and training, design reliability establishment and assurance, manufacturing reliability establishment and assurance, user reliability support, and engineering reliability activities. It is pointed out that a reliability program within any industrial enterprise must ensure that a product's inherent reliability exceeds its required operational reliability by a significant enough margin for all degradation influences to be recognized and adequately controlled. M.G.J.

Review: The development of reliable products in an industrial system requires policies of reliability planning and management as well as the technical competence necessary to assure the attainment of the reliability requirements. The managerial aspects of reliability become extremely important when developmental programs, products, etc., cross international boundaries. The purpose of this paper is to point out many factors of the managerial aspects of reliability and to establish guidelines to promote international unification of reliability practices. The paper expresses to a large degree an international consensus and should therefore be of value to managers engaged in international programs involving reliability. Additionally, the guidelines might serve as a checklist for establishing or evaluating a reliability management system. The reader should be aware of the paper, "Some International Aspects of Reliability and Quality" by E. H. Hayes (see our review R70-15106).

82 MATHEMATICAL THEORY OF RELIABILITY

R70-15221 ASQC 824; 838
Air Force Systems Command, Wright-Patterson AFB, Ohio. Foreign Technology Div.
DISCRETE AUTOMATA WITH MULTIPLE LINES
V. B. Svechinskii 26 Mar. 1969 20 p refs Transl. into ENGLISH from the publ. "Trudy Moskovskaya Konferentsiya Molodykh Uchenykh i Spetsialystov, 1st, 1964" Moscow, Izd-vo Nauka, 1967 p 206-217
(N70-18386; AD-696496; FTD-MT-24-50-69) Avail: CFSTI

The paper examines the problem of designing reliable discrete automatic machines from unreliable components. In particular, it is shown that it is possible to design a reliable computer with three-unit redundancy if the constraints placed on components are not too strict. A means of increasing computer reliability is to check the performance of the individual elements and to provide for recovery of the faulty elements. Several methods of introducing such checking and recovery operations are examined and the reliability of a computer with recoverable elements is assessed. A method of designing a computer with three-unit redundancy is proposed, which makes it possible to detect the failure of any of the elements and to continue operation by substitution (or recovery) of the faulty element. The results obtained are readily extendable to computers with higher-order redundancy. Author (TAB)

Review: This paper is a machine translation of Russian text; the few minor editorial oversights present no problem to the interested reader. The paper is directed primarily toward theoreticians. The title is not very indicative of the contents; the objective is to demonstrate the increased reliability that results from applying majority logic techniques to digital systems. The use of "multiple lines" in the title refers to redundant signal paths. The majority organ differs from that of von Neumann in that the output state is the complement of the majority of the input signals. This technique seems to have no particular advantage over the von Neumann scheme, other than the possibility of constructing a system which consists entirely of such majority organs. The mathematics was not completely checked but it appears to be correct. The paper consists largely of well-known concepts and will be of value mainly to those doing research in the field.

R70-15222 ASQC 824
TESTS FOR MONOTONE FAILURE RATE 2
P. J. Bickel (California University, Berkeley) *The Annals of Mathematical Statistics*, vol. 40, no. 4 1969 p 1250-1260 11 refs
(Contract NONR N00014-67-A-0114-0004)

Based on previously derived data, a result is established to the effect that under the regularity conditions of a theorem each one of four classes contains a test asymptotically equivalent to the asymptotically most powerful similar test. This is in sharp contrast to the situation where it has been shown that when the scale parameter is known three of the classes do not contain asymptotically most powerful tests and consequently the ranks are not asymptotically sufficiently. A.L.

Review: In this paper the author establishes a mathematical result pertaining to the power of four classes of test for the negative exponential distribution with unknown scale parameter against the alternative that the underlying distribution has a monotone increasing failure rate. The result was stated in an earlier paper by the author and an associate (see R68-13836). The problem to which this result applies arises in life testing situations. Thus, the paper makes a worthwhile contribution to the mathematical theory applicable to life testing. Substantial background in mathematical statistics will be required in order to follow it in detail.

R70-15223 ASQC 824
TESTS FOR MONOTONE FAILURE RATE BASED ON NORMALIZED SPACINGS
Peter J. Bickel and Kjell A. Doksum (California University, Berkeley) *The Annals of Mathematical Statistics*, vol. 40 no. 4 1969 p 1216-1235 19 refs
(Contracts NONR-3656(18); NONR-222(83); N00014-67-A-014-0004)

Mathematical proof is presented that asymptotic normality holds for sequences of alternatives that approach the H sub o distribution 1 − exp (− lambda t), t < or = 0, as n approaches infinity; and that Proschan and Pyke ratios of efficacies are in fact Pitman efficiencies. Statistics that are linear in the normalized spacings and asymptotically most powerful for parametric alternatives if the scale parameter lambda is known, are derived, and it is shown that the rank statistics that are asymptotically most powerful in the class of linear rank tests, are nowhere most powerful in the class of all tests, when lambda is known. If lambda is unknown, studentizing of the linear normalized spacing tests which are asymptotically most powerful for lambda known leads to procedures which have only the same asymptotic power as the most powerful linear rank tests. Unbiasedness is shown for tests that are monotone in the normalized spacings, and Monte Carlo power estimates are used to compare the various statistics with the likelihood ratio tests considered by Barlow. Author

Review: This is a revised version of the paper covered by R68-13836.

R70-15224 ASQC 824
ESTIMATION OF PARAMETERS IN A TRANSIENT MARKOV CHAIN ARISING IN A RELIABILITY GROWTH MODEL
M. Dubman and B. Sherman (Rocketdyne, Canoga Park, Calif.) *The Annals of Mathematical Statistics*, vol. 40, no. 5 1969 p 1542-1556 15 refs
(Contract AF33(615)-2818)

Results are given concerning the maximum likelihood estimation of parameters in a certain reliability growth model. Two formulations of the model are considered, leading to two related estimation problems. In the first formulation it is proved that the likelihood equations for the Markov chain y i, i < or = 0 have solutions which converge in probability to the true parameter values and which are asymptotically jointly normally distributed. In the second formulation, the reliability growth model is described by a sequence of independent random variables which are geometrically distributed. These variables are defined to be the number of trials for which the accumulated number of failures equals k. It is shown for both formulations of the reliability growth model that the likelihood equations have solutions which converge in probability to the true parameter values, and which are jointly asymptotically normally distributed. Author

Review: This is a revised version of the report covered by R69-14798.

R70-15230 ASQC 824
DETERMINING THE GAMMA-PERCENTAGE LIFE OF ENGINEERING PRODUCTS
Yu. N. Blagoveshchenskii and R. V. Kugel *Russian Engineering Journal*, vol. 49, no. 3 [1969] p 10-14 3 refs

In mechanical engineering practice the concept of the gamma-percentage life of a product is used, but adequate attention has not been given to the accuracy of the methods used. Nomograms have been constructed for use in determining the accuracy of gamma-percentage life for normal distributions. The principal parameter of this method is the coefficient of variance v = s/x, derived from the results of random tests. The nomograms are approximate, but enable the relative error of gamma-percentage life to be determined with sufficient accuracy even when n < or = 20. Several examples of the use of the nomograms are discussed. A.L.

Review: This paper is directed towards engineers who are trying to estimate a point on the cumulative distribution curve; for example, in the life of bearings, one often gets the B10 life, which is the life below which only 10% of the items can be expected to fail. The author emphasizes that without some knowledge of the uncertainty in the estimate, one can be greatly misled by his estimate. He then shows how standard statistical techniques can be used for the normal distribution and for non-parametric distributions in determining this uncertainty. The statistical techniques are not new, but they are not often applied by engineers. One of the big advantages in using a statistical method of estimation (vis a vis eye-ball estimates) is that this technique also allows an estimation of the uncertainty involved, which is extremely difficult to get graphically. The paper is somewhat difficult to read; there are the usual translation problems (although not serious) and an occasional misprint. Nevertheless, the message is an extremely important one and one to which every reliability engineer should pay attention.

R70-15231 ASQC 824; 831
Y-DELTA TRANSFORMATION THEOREM FOR RELIABILITY-FUNCTION CALCULATIONS WITH APPLICATION TO NON-SEPARABLE STRUCTURES
N. Millea (Electrical Engineering Research Institute, Bul. T. Vladimirescu 45-47, Bucharest, Romania) *Electronics Letters* 11 Dec. 1969 p 661-662 1 ref

A method is proposed to solve complex system reliability problems by successively reducing the structural model network to more simple equivalent configurations. Transfiguration theorems are given, valid when the component failure probabilities are not too high. Author

Review: The method presented in this paper can be of help to those who wish to break down very complex systems into simple ones. It is useful in calculating probabilities of failure of these complex systems; however, it would have helped had the author given some idea of the magnitude of the error in the approximation and how it might be corrected if one should wish more exact answers. Nevertheless, those who work with reliability logic diagrams should be aware of the idea in this paper. This seems to be the first time it has appeared in public print, and it deserves to be given more widespread distribution.

R70-15248 ASQC 824; 762
MATHEMATICAL SELECTION OF AN ECONOMIC QUALITY LEVEL FOR BATCH REWORK OPERATIONS
G. William Churchill (General Electric Co., Quality and Process Control Engineering, Auburn, N. Y. *In: American Society for Quality Control, Annual Technical Conference, Transactions, 24th, Pittsburgh, May 11–13, 1970* Milwaukee American Society for Quality Control, Inc. 1970 p 161-166 Avail: $13.00

The problem of balancing rework costs against the cost savings resulting from a lower reject level in the finished product is ana-

lized. A mathematical model of the interaction of the decision point and the affected operations was established to determine the effects of varying the decision point on the expected cost per good unit. This model was based on the following assumptions: (1) The product is produced and reworked in batches and therefore a sorting operation is impossible. (2) The distribution of the quality level, or batch % defective, is constant and known. (3) The loss in units during each rework is constant and known. An example of how this technique was applied to the planar process for the manufacture of semiconductor devices is given. Author

Review: This paper is on an important topic; unfortunately, it suffers from using a computer instead of simple algebra. If algebra had been used, many of the expressions would have been considerably simplified. Simple inspection of the equations then reveals the desired trends. For example, in this particular case, the figure-of-merit is not degraded appreciably by no rework at all. In that event; of course, other considerations come into play, i.e., those assumptions not put into the formulas—but the paper does not discuss what they might be. The ease of use of computers is not always an advantage; one can sometimes learn more by analyzing the mathematics more carefully.

R70-15253 ASQC 822; 425; 842

APPLICATIONS IN THE STEEL INDUSTRY OF THE 3-PARAMETER WEIBULL DISTRIBUTION

D. J. McMahon (Allegheny Ludlum Steel Corp., Research Center, Applied Mathematics Dept., Brackenridge, Pa.). *In: American Society for Quality Control, Annual Technical Conference, Transactions, 24th, Pittsburgh, May 11–13, 1970* Milwaukee American Society for Quality Control, Inc. 1970 p 275-281 5 refs Avail: $13.00

The 3-parameter Weibull distribution and graphical estimation procedure were used to describe the response behavior of sulfide inclusions in stainless steel bar and ingot samples, eccentricity of seamless tubes, crush lives of powder metallurgy parts, flex-test failures in golf shafts, and general fatigue failure data. The Weifull distribution was chosen based on either of two situations. First, the data frequency distribution appeared to be skewed and, therefore, the Weibull distribution was chosen simply as a curve-fitting technique. The second situation represents a mathematical judgment made by the analyst that the response behavior of the particular sample should be skewed to the positive side, prior to the observation of the data. The concept of a hazard rate, usually associated with reliability theory, is described to give the analyst some feeling as to when a skewed distribution may occur. Author

Review: The Weibull distribution is a popular one to use in reliability activities since the hazard rate can be increasing, constant, or decreasing depending on one of the parameters. This paper gives examples of the use of the Weibull distribution in fitting data. The graphical method of estimation was used, and is described in the author's reference 1. It is not clear that eyeball methods are necessarily good for estimating the guarantee period. An example of the difficulty with a guarantee period is given in the author's Figure 3, Example 3 wherein it looks very much as if some of the values of the random variable actually were smaller than the guarantee value. (It may be that some of the difficulty arises because of the very wide class intervals of the histogram, especially at the low values.) One of the tremendous benefits that a statistical estimation can provide, as opposed to eye-balling, is an estimate of the uncertainties involved. These can often be much larger than one has felt intuitively that they were, and they are of such magnitude as to radically change the conclusions to be drawn from the experiment. Point estimates are notoriously easy to imbue with an unwarranted sense of precision and accuracy. There are relatively simple linear estimators available for some of the parameters in the Weibull distribution. This article will be helpful mainly to those who are unfamiliar with the Weibull distribution.

R70-15258 ASQC 824; 542; 612; 846

AN APPROXIMATING FUNCTION FOR THE HAZARD RATE CURVE

P. M. Ghare and Y. H. Kim (Virginia Polytechnic Institute, Blacksburg, Va.) *In: American Society for Quality Control, Annual Technical Conference, Transactions, 24th, Pittsburgh, May 11–13, 1970* Milwaukee American Society for Quality Control, Inc. 1970 p 367-373 7 refs

(A70-31113) Avail: $13.00

Development of an approximating hazard rate function, and proposal of a procedure for estimating the parameters for this function from observed data. It is shown that the usefulness of a hazard rate function lies in the fact that, while a hazard rate function can be derived from the observed failure data (either in tests or in operation), it is a relatively simple procedure to translate the hazard rate function into estimates of reliability functions and failure probability functions. For this purpose a computer program has been developed and implemented on an IBM s60/65. The input consists of failure data observed over a time period. Computer output examples are shown in tables and diagrams. IAA

Review: This paper considers the brute-force problem of a least squares fit of the data to a very particular form of a hazard rate function. The function consists of two terms: the first one is decreasing and attempts to model the debugging period; the second approximates the wearout period, and the combination of the two generates the middle constant-hazard-rate. The solution does not exist in closed from; interative techniques must be used. There is no justification for the exact form shown; it contains five adjustable parameters and so ought to fit almost any kind of a curve reasonably well. In fact, the novice wants to beware of this type of curve fitting because it may not only fit the trend of the data but the vagaries of the data as well. The authors do not indicate that one should also estimate the uncertainties in the parameters and values of the hazard rate, as well as making point estimates. Estimating the uncertainties is very important, since without it one often is presuming much better numbers than he actually has. In this kind of problem, it would be a mistake to estimate the values of these parameters and use them for anything but interpolation unless in fact the uncertainties have been estimated. Otherwise, very gross errors could easily by made. There are simpler functions for the hazard rate available in the literature and simpler techniques for estimating them. Before using this one, an engineer should have competent mathematical and statistical advice.

R70-15259 ASQC 824; 223; 413

SOLUTIONS FOR THE WAGR SEQUENTIAL T-TEST: SEQUENTIAL VARIABLES SAMPLING PLANS TO CONTROL THE PERCENT DEFECTIVE

Robert L. Kirkpatrick (Bendix Corp., Kansas City Div., Statistics Section, Statistics Quality Control, Kansas City, Mo.) *In: American Society for Quality Control, Annual Technical Conference, Transactions, 24th, Pittsburgh, May 11–13, 1970* Milwaukee American Society for Quality Control, Inc. 1970 p 375-386 7 refs Avail: $13.00

A numerical solution is given for the acceptance and rejection equations of the WAGR test, which is a sequential variables sampling plan to control the percent defective where the mean and standard deviations are unknown. A FORTRAN computer program to obtain numerical results is presented, along with numerical and graphical results as examples, and a sequential variables sampling plan to control the percent defective based on the average and average range. Author

Review: This is a theoretical paper dealing with mathematical statistics. As such, an understanding of the paper is accessible only to those with a firm background therein. A mathematical and computer solution for the variables sequential-sampling plan is provided. The author has performed a service in giving these results. (It would, however, have relieved the curiosity of many readers if the initials WAGR had been explained. In a private communication, the author has stated that the explanation of WAGR is given as a footnote in Reference 3 of the paper. Roughly, the name stems from the initials of the individuals who suggested and developed the test: Wald, Arnold, Goldberg, and Rushton.) The tests are not truncated in any way. An ASN or OC curve was not provided. The conditions shown in Table 1 have a 10 to 1 ratio between the accept and reject percent defectives; this shows how difficult it is to distinguish very high reliability from not so high reliability. In deciding whether or not to use such a plan, the engineer and his statistician will have to decide whether the extra complications in analysis for the variables sequential plan are worthwhile and whether the more restrictive assumptions are justified. Generally, one does not get these more efficient plans without paying a price and that price is a much more detailed knowledge of the failure process than is necessary for attributes sampling. But the rewards are correspondingly great if those assumptions are justified. In general, one will not really know whether they are justified or not, and he must be careful not to get involved in what can degenerate into a numbers game. Sooner or later engineering confidence has to supplant statistical confidence.

R70-15269 ASQC 824

MODEL OF FAILURE FLOW OF AUTOMATION EQUIPMENT IN THE CASE OF RANDOM STATIONARY EXTERNAL DISTURBANCES

B. L. Solyanik and M. A. Yastrebenetskii (*Avtomatika i Telemekhan, Jul. 1969, p 175-184 In Russian.) Automation and Remote Control,* vol. no. 7, p 1172-1179 1969 16 refs

The effect is considered of randomly varying external disturbances on the failure flow of complex equipment. A statistical method of investigation of the flow is presented. In an example of an actual flow, it is shown that neglecting the external disturbances may cause appreciable errors in the statistical processing of the flow. Author

Review: The exponential reliability function occupies a virtually hallowed place in reliability theory largely because of its tractability and the fact that in many cases of practical interest, the hypothesis is accurate enough. Yet there is always the feeling that one could do better—this paper is one of the attempts to do better. It partially maintains the constant hazard rate hypothesis, but says that from time interval to time interval this hazard rate changes in a random fashion. The variance is then no longer equal to the mean; it is always larger than the mean and the author feels that this extra variance better explains observed data. The paper is theoretical. The results would be extremely difficult for reliability engineers except those most statistically competent) to apply, and they tend to be rather dependent on the nature of the random process which generates the fluctuating hazard rates. Thus, the paper is interesting to the theoretician, and, if sufficiently more work were done (including a great amount of publicity), it might have practical application for reliability engineers. The above comments are not meant to deter anyone from trying to fit his experiences with this model should he want to do so, but rather they point out the difficulties involved in so doing.

R70-15270 ASQC 824

A CLASS OF SEQUENTIAL TESTS FOR AN EXPONENTIAL PARAMETER

D. G. Hoel and M. Mazumdar (Westinghouse Research Labs., Pittsburgh, Pa.) *Journal of the American Statistical Association,* vol. 64, no. 328 Dec. 1969 p 1549-1559 4 refs

Sequential procedures are developed for testing an exponential parameter with prescribed levels of errors so that the average sample number is minimized at a third point lying in the indifference region. Also indicated is how to choose the third point so that sampling plans which approximately minimize the maximum expected sample size are obtained. An invariance property of the stopping region is presented which simplifies the construction of the Bayes region. Several sampling plans are given, and some of the properties are obtained. M.G.J.

Review: This is a theoretical paper with practical implications. Since the exponential distribution is so widely used in reliability work, there is naturally a great deal of interest in tests for the exponential parameter. The advantages of sequential tests for this parameter are generally known (as well as their disadvantages), and some effort has been taken in the past both to encourage the use of sequential tests and to provide exact determinations of the risks for a given truncation. The potential practical utility of this paper in running reliability tests is that it provides another degree of freedom for optimizing such tests. Before it can be used by reliability and quality control engineers, however, extensive tables will have to be generated and widely distributed.

R70-15271 ASQC 824; 838

THE EFFECT OF AN AGE REPLACEMENT TO A STANDBY REDUNDANT SYSTEM

Hisashi Mine and Tatsuyuki Asakura (Kyoto University, Japan) *Journal of Applied Probability*, vol. 6, no. 3 Dec 1969 p 516-523 8 refs

A multiple unit standby redundant system with preventive maintenance is presented. The Laplace transform of the probability density function of the time to the first emptiness for the system and its mean time are derived. As a special case, a two-unit standby redundant system with preventive maintenance is investigated in detail. Author

Review: This is a terse, mathematical paper which analyzes a very specific problem. It is difficult in such cases to give adequate word descriptions. The properties of the repaired and inspected systems are described, of course, by the equations; and the descriptions attempt to translate those into words. The paper then analyzes the behavior of a model of the system which has that exact behavior. Many mechanical or complex electrical/mechanical systems do not have the properties associated herewith. Minor repairs leave the system in a "bad-as-old" state; a complete overhaul will improve the situation somewhat, but some components will still not be as good as new. For example, one may rebuild an engine in an automotive vehicle without rebuilding the transmission

or the differential. Furthermore, not all inspections are done without damage to the system nor are all repairs done perfectly. Thus, it is extremely important to remember that a particular model is analyzed and that, when translating the mathematics into an actual system, considerable ingenuity is required of the reliability engineer. Analyses such as these can be helpful for those who wish to investigate the effects of various kinds of maintenance policies. The reasonable list of references helps give a sense of completeness to the paper. The ordinary practicing design and reliability engineers will have little use for this material.

83 DESIGN

R70-15217 ASQC 831; 844
Federal Electric Corp., Houston, Tex.
PROBABILITY OF EOSS MISSION SURVIVAL: EVALUATION OF THE IMPACT OF ARTIFICIAL GRAVITY OPERATIONS ON THE OVERALL MISSION RELIABILITY Preliminary Report
M. J. Seebach 1 Mar. 1968 25 p refs
(Contract NAS8-20412)
(N70-10029; NASA-CR-102291; AS-S-16-68) Avail: CFSTI

This analysis evaluated both qualitatively and quantitatively the effects on overall Early Orbital Space Station mission reliability of having artificial-gravity operations performed as part of the mission. The additional hardware and operations required for the artificial-gravity mode results in a reduction in overall EOSS reliability of approximately 1.0 percent. Artificial-gravity operations results in additions and changes to the following systems which degrade the overall reliability of the space station and/or degrade their operation: (1) electrical power system, (2) reaction control system, (3) stabilization and control system, (4) communication and data management system, (5) structural and mechanical system, (6) environmental control life support system, and (7) crew systems. It is recommended that analyses be performed as soon as possible to determine the impact of artificial-gravity operations on safety, escape, failure detection, and EVA operations. Author

Review: It may be necessary to provide, either on a periodic or continuous basis, gravity forces in the operation of an orbital space station to insure crew effectiveness, health, etc. Since NASA's Early Orbital Space Station (EOSS) configuration is to operate in a zero-gravity mode, it is necessary to calculate the resulting reliability of the EOSS due to the additional hardware and operations required if artificial gravity is to be proved as a part of the mission. The purpose of the report is to provide information on the impact that artificial gravity operations will have on the probability of success of an EOSS mission. The report does not represent a detailed study of the reliability of the space station, rather it discusses qualitatively the reasons for the change in the reliability of its systems, and calculates the mission reliability as a result of the added complexity required to support artificial gravity operations. All reliability figures concerning the EOSS systems are taken from previously published reports and the reader must consult the references to gain an appreciation of the reliability calculations. Areas which need additional consideration are pointed out. The reader who is not associated with this program may find a few unfamiliar terms and acronyms. The report will be useful in determining the most effective configuration to accomplish mission goals.

R70-15234 ASQC 830
Army Electronics Command, Fort Monmouth, N.J. Electronic Components Lab.
DESIGN OF A HIGHLY RELIABLE 75-watt RF BROADBAND AMPLIFIER
Dennis W. Bowman Jun. 1969 25 p refs
(N69-39046; AD-690790; ECOM-3134) Avail: CFSTI

This report describes the design, construction, and testing of a broadband 30 to 75 HMz RF amplifier capable of 75W of output power. It also describes the design of the amplifier with emphasis on load mismatch protection and techniques used to achieve high reliability. The performance data obtained will serve as a guideline for future designs of highly reliable RF power amplifiers. Author (TAB)

Review: This report discusses a feasibility study which was aimed at improving the reliability of a broadband amplifier. The report is not concerned with the total amplifier design, rather, it concentrates on a means of making reliable use of the amplifier's R.F. transistors. The author's purpose is to provide design engineers with a guide for improving the operating reliability of transistors. The proposed technique protects transistors against high power dissipation by using sensing circuitry which regulates bias voltages. The technique appears sound and certainly provides protection for the amplifier's transistors; however, the effect of the added circuitry on the overall amplifier reliability is not examined. There is much emphasis on the amplifier itself and little on the methodology for preventing transistor overstress and the resulting reliability. The report is clearly written and design engineers will find the contents worthwhile.

R70-15236 ASQC 830
DESIGN OF A RELIABLE MULTIPLE CONTACT FOR THE COIN TELEPHONE TOTALIZER
John P. Ellis (Bell Telephone Laboratories, Inc., Indianapolis, Ind.) *(Holm Seminar on Electric Contact Phenomena, Chicago, Nov. 11-14, 1969.)* IEEE *Transactions on Parts, Materials and Packaging,* vol. PMP-5, no. 4 Dec. 1969 p 161-170 5 refs

The totalizer performs many of the logic functions in handling a call from a public telephone set. It registers the denomination of the coin deposited and pulses appropriate signals back to the central office by transferring four sets of contacts, which are operated by a falling coin. The energy available from the coin is quite low, so contact force and cam rise of the switches must be kept low. Satisfactory operation of the contacts is essential to reliable service from the telephone. Public telephones are subjected to extreme environments, and early trials indicated contact contamination might cause the totalizer to fail to meet desired performance levels. The contact design was reviewed from three aspects: analysis of field failures, analytical investigation of design parameters, and laboratory testing to establish relative reliability figures. Considerations leading to the adoption of a brush of four precious metal wire contacts as the design to be used in production are summarized. Author

Review: The first part of this paper reviews the conditions under which the relay must operate, and the second part describes the various considerations in deciding on the kind of multiple contact. The paper is a very good case history; it will be of value largely to those concerned with relays, but reliability engineers in general may wish to see how the problems were isolated, attacked, and tested. The descriptions are generally good. There is a reasonable use of jargon, but it will not interfere too much with the non-specialist's attempt to get something from the paper. The paper shows

how the use of reasonably simple mathematical models can indicate the direction in which one should go toward solving the problem. Knowing how exact and complicated one needs to get in the calculations is an important part of any design improvement.

R70-15244 ASQC 832; 880

RELIABILITY OF ARTIFICIAL KIDNEY SYSTEMS

Robert L. Cooley (Burton Research Labs., Culver City, Calif.) and Edwin A. Pecker (Bio/Systems, Inc., Santa Monica, Calif.) *In: American Society for Quality Control, Annual Technical Conference, Transactions, 24th, Pittsburgh, May 11-13, 1970* Milwaukee American Society for Quality Control, Inc. 1970 p 99-109 6 refs

Avail: $13.00

An overview is presented on the basic principles involved in hemodialysis, the equipment requirements for an automatic self-contained home dialysis system, and the definition of reliability as applied to this type of system. The case study of a home machine is presented to illustrate the details of these principles as applied to equipment currently in general use by home dialysis patients. The concept of psychological reliability in such man-machine systems is considered. The balance between maximized patient's safety and minimized initial and continuing equipment costs is discussed. Author

Review: This is a good paper which makes some important points. It is on a topic relatively unfamiliar to reliability engineers, and there is a brief, but adequate, description of the system written so that engineers can understand it. The technical reliability objectives are quite straightforward. The author then introduces what he calls *psychological reliability* and shows succinctly how and why it is important, especially in a medical instrument for home use such as the artificial kidney. It involves the operator interaction with the system, the faith which he puts in the information it gives him, and how much stress he is under in making use of that information for further action. Even though many reliability engineers are nominally familiar with the problem, it is one which is not often discussed in print, and one which arises in many places—even aerospace systems.

R70-15245 ASQC 832; 340; 761; 880

QUALITY CONTROL OF MEDICAL DEVICES WITHIN THE HOSPITAL

Joel J. Nobel (Emergency Care Research Institute, Philadelphia, Pa.) *In: American Society for Quality Control, Annual Technical Conference, Transactions, 24th, Pittsburgh, May 11-13, 1970* Milwaukee American Society for Quality Control, Inc. 1970 p 111-113 13 refs

Avail: $13.00

The fact that approximately 5000 different types of patient-related devices are found in a typical hospital inventory is given as proof that strict quality control of such devices is mandatory. It is pointed out that quality control in the broadest sense of the term must be extended to encompass conception, design, development, engineering and clinical test and evaluation procedures, manufacturing, inspection, and shipping. A program plan, evolved to cope with these problems, is outlined. The plan concentrates on prevention of problems, first by direct involvement in selection and purchasing, and then by direct participation in personnel training and bedside application of hardware. M.G.J.

Review: Quality and reliability in medical devices is of concern to everyone as an individual and is of concern to reliability engineers in their professional capacity. Much of the contemporary reliability developments are derived from the aerospace and defense industries, although much of this knowledge is yet to be put into effect. The first part of this paper tells what is wrong with the medical instrument business, what damage is done by defective instruments, the dishonesty, misrepresentation and incompetence in the field on the part of both physicians and manufacturers. The remainder of the paper explains the virtues of the service offered by the author's organization, and indeed, they are reasonable. The main thrust of the paper is that quality control of medical equipment must be reviewed as a very broad concept encompassing conception, design, development, engineering, clinical testing and evaluation, manufacturing, inspection, shipping, pre-purchase selection, incoming inspection, preventive and unscheduled maintenance, training and clinical application rather than, traditionally, manufacturing quality control alone. Emphasis is placed on prevention and the application of judgment before a problem arises. These are good ideas which should be implemented, not only for medical equipment, but also for other kinds of hardware. They constitute criteria which should be used in evaluating *any* organization having quality control/reliability responsibilities. It is also probable that suitable standards developed by the medical and manufacturing industries in conjunction with each other would facilitate the removal of poor equipment from consideration; for example, requiring a stamp of approval from an organization analogous to the Underwriter's Laboratories. The paper implicitly demonstrates two important functions of any reliability effort: (1) finding the kinds of details to which attention must be paid and then (2) ensuring that attention is in fact paid to them.

R70-15256 ASQC 831; 817; 825; 838

SYSTEMS EFFECTIVENESS APPORTIONMENT TECHNIQUE OBSERVING CONSTRAINTS ON ACCOUNTABLE FACTORS

Erich Pieruschka and S. E. Van Vleck (Lockheed Missiles and Space Company, Sunnyvale, Calif.) *In: American Society for Quality Control, Annual Technical Conference, Transactions, 24th, Pittsburgh, May 11-13, 1970* Milwaukee American Society for Quality Control, Inc. 1970 p 345-353

(Contract F30602-67-C-0182)

(A70-31111) Avail: $13.00

Study of the problem of apportioning system effectiveness when constraints exist on the accountable factors, using the Lagrange multiple method. The discussed apportionment method is demonstrated for two different system effectiveness functions. The first system effectiveness function is assumed to consist of the reliability parameter only. This apportionment method is demonstrated for a complex system effectiveness function which contains the availability, reliability, and performance parameters. IAA

Review: This is a mathematical paper which describes the Lagrange multiplier method for solving a maximization problem in the presence of constraints. In this case, the constraints are inequalities and are generally replaced by the equality during solution. The authors assert that this apportionment technique guarantees an optimum. Since the constraints are linear, this may be so; but in general, of course, the method of differentiation achieves only a stationary point which may be a local maximum, a local minimum, or neither. In most cases of practical interest, the only solution within the appropriate region is the one desired. The paper is somewhat difficult to follow because of its terseness, but the several detailed examples do help. The dif-

ficulty of solving a problem with Lagrange multipliers is glossed over somewhat; it can be a lengthy and difficult task especially if the functions are at all complicated since often the solution cannot be found in closed form. Before an engineer attempts to use the method, he should go over the derivations in detail or have a competent mathematician go over it for him to be sure that the methods advocated here are satisfactory for his problem.

R70-15260 ASQC 837; 122; 130; 420; 822

STATISTICAL TOLERANCES BY NUMERICAL INTEGRATION

David H. Evans (Oakland University, School of Engineering, Rochester, Mich.) *In: American Society for Quality Control, Annual Technical Conference, Transactions, 24th, Pittsburgh, May 11–13, 1970* Milwaukee American Society for Quality Control, Inc. 1970 p 395-399 5 refs Avail: $13.00

Based on previously derived data, three ways of analyzing component tolerances are discussed: (1) If the relationship between the response X and the values of the components is a known function, then a direct calculation may be performed. (2) Simulation of Monte Carlo methods may be used. (3) The distribution of the response may be characterized by the use of numerical integration techniques. These results are extended to the case where the restriction that all of the component distributions are normal is removed. In practice, this means that the numerical integration technique is competitive with (1) and will work when (1) is not applicable, and is superior to (2) in all cases except the unusual one where a Monte Carlo approach is needed to produce greater precision than is available by numerical integration. Author

Review: This is a theoretical paper and the results are accessible only to those with a fairly good background in mathematical statistics. The basic ideas, however, are easily understandable by quality control and reliability engineers. The mathematics was not checked in detail, but the assumptions are clearly stated and the techniques seem reasonable. The difficulties in application will not lie with solution of formulas, but rather with difficulties in the overall tolerancing system. The author mentions some of them, and they should be heeded. If very low probabilities of failure are required, the method becomes rather sensitive to the assumed shape of the distribution in the tail region, which is where the distribution is least known and most uncertain. While statistical tolerancing in its various forms including the calculation of reliability is often advocated in the literature, it appears to be much less often done in practice because of the training involved and then pushing of conceptual models further than they can be pushed sensibly. A worst-case analysis is often justified, for example, not on the basis that is gives exact results but that it is easy to calculate and that it helps account implicitly for the many factors that were not explicitly considered in the model. If statistical tolerancing is to be used, there are some simplifications which can be introduced. For instance, the Gaussian distribution can be introduced much sooner in the problem if the coefficients of variation are small and each dimension (or some transformation thereof) can be assumed to be *normal*, then the deviations in the desired parameter will also be *normal*, with parameters calculated by the usual approximations (the model is linearized since deviations from the mean are assumed to be small). It is not clear at this time and without extensive trials just how practical the author's method will be. Certainly, it is one which should be considered by anyone wishing to improve the operation of his quality assurance department, but just as certainly it is not a method which should be applied blindly.

R70-15276 ASQC 838; 824

OPTIMUM ADAPTATION ALGORITHM FOR REDUNDANT STRUCTURES WITH VARIABLE-THRESHOLD RESTORING UNITS

S. M. Domanitskii (*Avtomatika i Telemekhanika, no.*8, *Aug. 1969, p 167-174 In Russian.*) *Automation and Remote Control,* vol. no. 8, 1969 p 1335-1341 1 ref

A method for determining the optimum adaptation algorithm for redundant logical structures with variable-threshold restoring units is described. The initial redundancy and the adaptation algorithm are determined on the basis of a probable penalty for spurious 0 and 1 signals at the structure's output not exceeding the assigned value. The method can be applied to redundant structures with an equal or unequal probability of spurious 0 and 1 signals at the outputs of the operating logical units. The reliability of the inspection and adaptation system is considered in determining the optimum algorithm. Author

Review: This is a highly theoretical paper which seeks to determine the optimum adaptation algorithm for a class of redundant logical structures; it is intended for those persons engaged in research in the field of adaptive systems. The paper is not easily readable and is not particularly enlightening because of the author's reliance on a previous publication (the author's reference no. 1) for details. The reader interested in this area will find Pierce's work on adaptive decision elements of value [1].

Reference: [1] Pierce, W. H., *Failure-Tolerant Computer Design,* Academic Press, New York (1965).

R70-15278 ASQC 830

Safety in Mines Research Establishment, Buxton (England).

SOME ASPECTS OF THE DESIGN OF INTRINSICALLY SAFE CIRCUITS

D. W. Widginton 1968 25 p refs

(PB-188763; SMRE-RR-256) Copyright. Avail: HMSO 5s 6d; BIS $1.10; CFSTI

The report reviews the basic information usually available to the circuit designer, and then discusses the problems involved in the design of intrinsically-safe circuits. Topics covered include the design of voltage-stabilized dc and ac supplies; the design of inductive circuits, with and without protective shunts; and methods for assessing the effects of long interconnecting cables. A useful method of assessing the safety of certain circuits is to show that the circuit under consideration is less dangerous than another circuit, whose safety can be assessed in terms of the basic information available. Author (USGRDR)

Review: The title of this report could be misleading: the term "intrinsically safe" refers to circuits which are designed to operate safely in a hazardous environment (e.g., methane–air mixtures) and not to those circuits which are fail-safe or employ some form of redundancy for failure protection. Obviously, a hazardous environment requires special design considerations for ensuring both the reliability and safety of electrical equipment. This clearly written tutorial report is intended to supply circuit designers with some of the basic tools and techniques for designing this kind of intrinsically safe circuit. In particular, the newcomer to this field should find this report useful.

R70-15279 ASQC 830; 839

A PROCESSOR FOR IMPLEMENTING SPIF TECHNIQUES FOR SELF-REPAIR. PART 1: THEORY AND ALGORITHM; PART 2: DESIGN GOALS AND PROGRAM OPERATION

David C. Roberts (Informatics, Inc., Bethesda, Md.) *Computer Design*, vol. 8, no. 12, Pt. 1, Dec. 1969 p 59-64 6 refs and vol. 9, no. 1, Pt. 2, Jan. 1970 p 63-69 4 refs

A technique based on the Sequential Prime Implicant Form (SPIF) for monitoring and detection of errors in sequential circuits, without increasing the number of external connections, is discussed. This concept permits the application of the tools of combinational switching theory to sequential switching networks. A general introduction to the SPIF theory and a discussion of the algorithm for self-repair are given in Part 1. A description of the computer program for finding the nodes of a network that must be monitored in order to detect an improper state transition, and an example of the operation of the program are presented in Part 2. A.L.

Review: Sequential prime implicant form (SPIF) is a concept which permits the application of the tools of combinational switching theory to sequential circuits. This paper is directed primarily toward design engineers concerned with error detection in sequential circuits. It deals with the problem of finding a minimal set of circuit failures that alter the state graph of the network. The self-repairing technique involves the switching of a spare network into the operating structure of a system following the detection of an error by monitoring circuitry. Part I is an introduction to SPIF theory and its potential for self-repair; Part II is a description of a computer program for finding the nodes of a network that must be monitored in order to detect an improper state transition. The reader who is interested only in the technique need not read Part II. The major weakness in the author's discussion is that no consideration is given to the errors that might occur in the circuit output. Because (1) the technique does not completely check a sequential circuit and (2) it requires monitoring internal nodes that may not be readily accessible, its value is limited; however, the SPIF technique is certainly a step in the right direction.

84 METHODS OF RELIABILITY ANALYSIS

R70-15218 ASQC 844; 782
Royal Netherlands Aircraft Factories Fokker, Amsterdam.
EFFECT OF SPACE ENVIRONMENT ON MATERIALS
P. C. van der Waal 4 Jul. 1968 40 p refs
(N69-36884; RV-22) Avail: CFSTI

The origins and the problems of outgassing are discussed. Experiments are described where adhesives for metal bonding and fiberglass reinforced plastics were exposed to a thermal vacuum environment. Some of the adhesives show a loss of strength of more than 10% after 20 days. Weight loss curves obtained from the plastics provides more information about the behavior of these materials. Author

Review: This paper presents a good tutorial review of the effects of a space environment on materials. Outgassing of materials in space vehicles may interfere with the functional parts of the vehicle. The author's purposes are: (1) to inform the reader of the nature and effects of outgassing and (2) to describe an experiment (with its results) conducted in a thermal vacuum environment on commercially available products. The paper is highly readable and will give the reader a better understanding of outgassing phenomena.

R70-15219 ASQC 844
National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, Ala.
ASSESSMENT OF RELIABILITY OF METAL OXIDE SILICON DEVICES
Leon Hamiter and Ben Bagley [1969] 26 p refs
(N69-37296; NASA-TM-X-61837) Avail: CFSTI

This paper assesses metal–oxide–silicon (MOS) monolithic microcircuit usability and reliability as they affect possible use for certain space applications. Predominant failure modes and mechanisms are identified, failure rates are quantitatively assessed, and quality standards and test programs to reduce failures are recommended. User and manufacturer data presented substantiate a reasonable reliability and indicate MOS device suitability for high reliability use when properly controlled. Author

Review: The purpose of this paper is to compare the reliability of MOS circuits with that of the more familiar bipolar technology and to demonstrate that one no longer pays a performance penalty when choosing MOS. In the course of arguing that MOS circuits are now ready to be used in much the same manner as bipolar circuits, the authors cite the failure rates measured at Goddard Space Flight Center during three orbital spacecraft missions over recent years. The measured failure rate is 0.018%/1,000 hours at a 60% confidence level. Two failures were observed in 17 million circuit hours; both occurred after the first year of flight. These numbers are comparable to contemporary bipolar circuit performance. The type of failure that is observed in MOS circuits is not substantially different from those encountered with bipolar circuits, although precautions unique to MOS must be taken in handling them to avoid static charge buildup on the gates. Other failure modes seem much the same and can be screened by a procedure similar to those for high-reliability bipolar circuit lines at present. Not much has been published previously on long-term MOS circuit performance and reliability analysis. The statistical data assembled here convince the reader that MOS has arrived in a reliability sense. One serious omission is associated with the labels of Figure 3 which compares the types of MOS circuit failures with those of bipolar circuits. Unfortunately, insufficient labels appear in the figure to enable the reader to distinguish which graph applies to bipolar and which to MOS. Presumably the unlabeled graph is the bipolar, while graphs labeled manufacturer A and manufacturer B describe representative MOS manufacturers.

R70-15227 ASQC 844; 775
NEED ADVANCE WARNING OF THRUST BEARING FAILURE?
Donald E. Bentley (Bentley Nevada Corp., Minden, Nev.) *Hydrocarbon Processing*, vol. 49 Jan. 1970 p 111-114 Gulf Publishing Co.

Non-touching, eddy current, electronic micrometers can be used successfully for accurate thrust position measurements. Thrust position measurements made on rotating machinery can be used to accurately indicate thrust bearing failure. With an advanced warning, damage to the machine can be limited to the loss of a thrust bearing. Author

Review: Even though this paper concentrates on thrust position measurements of rotating machinery parts, it has wider applicability to other proximity-measurement applications, especially where eddy current probes are appropriate. It is a very good paper on the practical aspects of making measurements using the eddy current principle and will be worthwhile reading for anyone con-

sidering or relying on the technique. It is not cookbookish in the sense of telling how to conduct such measurements, but is more a set of guidelines on telling what the potential problems are and of what the person planning or conducting the test or analyzing the results should be wary. It is easy to tell that the author writes from experience. Articles of this type fill a great need in the area of nondestructive evaluation. More, written by persons with in-depth experience, are needed on other specific techniques in reliability, testing, and other areas of engineering.

R70-15232 ASQC 844

BASIC COURSE IN FAILURE ANALYSIS. LESSON: HOW PARTS CAN FAIL, IMPORTANCE OF STRESS; LESSON 2: PLANNING FOR STRENGTH; LESSON 3: FAILURE MODES; LESSON 4: BENDING FRACTURES

Charles Lipson (Michigan University, Dept. of Mechanical Engineering, Ann Arbor, Mich.) *Machine Design* Oct. 16, Oct. 30, Nov. 13, Nov. 27, 1969 p 146-150, 108-112, 222-225, 140-143 4 refs

Four parts of an eight lesson course on the basic failure mechanisms that must be considered in the design of any part are presented. These include: (1) Basic ways components fail, including strength and wear considerations, and practical suggestions on where to begin to solve the failure problem. (2) Basic strength factors of materials and an approach to understanding such practical considerations as fluctuating loads. (3) Basic failure modes, reasons for their occurring, and some common variations that can be expected. (4) Causes of bending fractures and methods of recognizing these fractures from the appearance of a failed cross section.

A.L.

Review: These first four lessons will best serve the designer who has had some experience in the field, enough to have a ready framework within which to place the points the author is making. The articles are good for this purpose, and indeed most designers should refresh their memories with a series such as this every few years in order that they stay aware of all of the things that can go wrong. The author has an excellent emphasis on the fact that strength is not a simple quantity but has many phases or facets. Designers should especially beware of a material which is touted to have an extremely high strength, since most often only one or a very few such phases are being considered. For example, metals with extremely high tensile strength may be brittle or very susceptible to notched fatigue. In Lesson 2 (Planning for Strength), not all of the deleterious combinations of environments have been called out—the list would probably be too long. The designer who is not extremely familiar with the application and with the metal being considered should consult a metallurgist. Papers such as this can help him understand the language the metallurgist will be talking. For example, many alloys will change from being ductile to being brittle as the temperature is decreased. Also, fabrication methods such as welding can alter the properties of the parent metal, e.g., near the weld zone. The designer must also remember that (1) typical handbook values and curves such as shown in this set of papers give average or typical values, (2) there is a great deal of scatter in individual specimens about this value, and (3) there is a great deal of uncertainty in the behavior of many materials. For example, there are heat-to-heat and lot-to-lot variations that can be important. Not all material bought for a particular specification will even meet that specification (your supplier is no more perfect than your own company). It is not only mechanical designers who should be familiar with the material in these lessons. Electrical designers and reliability engineers should also have an awareness of these modes of failure of mechanical parts, since many of the failures in electrical equipment can be attributed to mechanical problems. Designers ought to develop checklists which they can use when applying a new alloy or in running across a new application especially since the pressure is on to get the most out of materials and to make extremely reliable products. It is easy to overlook a failure mode or mechanism that can cause trouble. The kinds that no one thinks can even happen will cause enough difficulty, so we should always at least do the best that we can now. These lessons are a valuable adjunct in that activity.

R70-15233 ASQC 844

FRICTION AND WEAR-LIFE OF SELECTED SOLID LUBRICANT FILMS AT -100 F, R.T., AND 400 F

Vern Hopkins and Mahlon Campbell (Midwest Research Institute, Kansas City, Mo.) *(American Society of Lubrication Engineers, Annual Meeting, 24th, Philadelphia, May 5-9, 1969.) Lubrication Engineering,* vol. 25, no. 11 Nov. 1969 p 430-435 6 refs (Contracts NAS8-1540; NAS8-21165)

(A69-30471) Avail: Members, $0.75; nonmembers, $1.50

Friction and wear-life results are presented for 22 selected films, determined in three contact configurations: (1) a pin between two "V"-blocks (Falex tester), (2) three flat pellets on a flat surface, and (3) a journal and shaft. Both standard Falex load-carrying and wear-life tests are conducted. Pellet-type tests are run at one sliding speed (765 ft/min), two loads (2.2 and 13.5 psi), three temperatures (−100°F, room temperature, and 400°F), and two atmospheres (10^{-6} torr and dry nitrogen, at normal atmospheric pressure). The vacuum environment is used only during the −100°F tests. The 2.2-psi load is used at all temperatures, but the 13.5-psi load is used only at room temperature. Journal-bearing tests were conducted in normal laboratory air environment at 300 psi and 100 rpm (4.92 ft/min) as well as at 10,000 psi and 20 rpm (0.984 ft/min). Results are discussed for temperature and load effects and for the correlation from tester to tester.

Author (IAA)

Review: Friction coefficient and wear-life are very important characteristics of lubricants, but, as the authors have shown, they are also very elusive characteristics. The values not only vary randomly from sample to sample, but the relative ranking can depend on the kind of test methods used. Nevertheless, designers do have to make decisions, and they need data upon which to base them. This paper provides a very good source of such data. The authors have made no attempt to minimize the uncertainties involved; in fact, they have taken care to point them out. A designer or reliability engineer can also learn a great deal about lubrication and wear by reading the authors' discussions; they are not very long and they use a minimum of technical jargon. Papers such as this are a valuable addition to the engineering literature.

R70-15235 ASQC 844; 775

Mechanical Technology, Inc., Latham, N.Y.

DEVELOPMENT AND EVALUATION OF SOME MECHANICAL WEAR DETECTION SENSORS

Frederick K. Orcutt Jun. 1969 66 p refs (Contract N00014-67-C-0500)

(N69-39119; AD-690447; MTI-69TR34) Avail: CFSTI

Several types of sensors have been developed for the purpose of monitoring the operation and detecting incipient failure of critical mechanical components. They include sensors for in-line quantitative measurement of wear particles present in the lubricant and an integral bearing-sensor for direct measurement of the dynamic

force transmitted from a rotating assembly to the structure. These and other, more established, sensors have been applied to several mechanical systems to gain experience in their use and for comparative evaluation of their effectiveness as monitoring and failure detection concepts. Experiments were performed with a small gasoline engine and with a power gear system using commercial gearboxes. Author (TAB)

Review: A requirement for a reliable, maintainable system is failure detection and, if possible, a warning of impending failure. The use of nondestructive evaluation to improve system reliability is on a beneficial increase. This clearly written report is concerned with nondestructive detection of excessive wear of critical mechanical components by monitoring the quantity of particles entrained by the system's lubricant. Two purposes are served by the report: (1) it reviews sensor techniques which are useful in measuring the quantity of wear particles in the lubricant, and (2) it discusses the results of experiments which were performed in order to evaluate various wear detection concepts and to demonstrate the value of the techniques for detecting excessive wear of certain mechanical systems. This interesting report will be of value to mechanical maintenance engineers as well as design and reliability engineers who are concerned with evaluating the reliability of mechanical designs.

R70-15242 ASQC 844; 775

NEW NON-DESTRUCTIVE TESTING TECHNIQUES INSURE RELIABILITY OF COATINGS

R. C. Stinebring (General Electric Co., Re-Entry and Environmental Systems Div., Philadelphia, Pa.) and W. L. Shelton (USAF, Materials Lab., Wright-Patterson AFB, Ohio) *Space/Aeronautics*, vol. 53, no. 2 Feb. 1970 p 54, 55, 57, 59, 60, 62
(A70-22679)

Description of non-destructive testing techniques for evaluating the qualities of diffusion-formed refractory-alloy coatings intended for oxidation protection of hypervelocity aerospace vehicles and reusable systems exposed to elevated temperatures over extended periods of time. According to one of these techniques niobium specimens covered with chromium-titanium-silicon coatings are treated with a fluorescent dye dissolved or suspended in a low-viscosity oil which remains in cracks and pores when the surface is cleaned. A developing agent and UV light are then used for detecting and examining the cracks and pores. Another technique uses a simple, highly sensitive thermoelectric instrument for measuring the thickness of coatings as function of voltage at points of contact. These techniques are in the process of evaluation on coated refractory rocket nozzles, experimental gas turbine components and prototype reentry vehicle structures. IAA

Review: Reusable reentry systems for future space missions require materials that can withstand extremely high temperatures during many missions. Under development are diffusion-formed coatings to provide oxidation protection for materials which have excellent strength properties at high temperatures but must be protected by an oxidation-resistant coating. The purpose of this paper is to describe new non-destructive test and evaluation techniques that have been developed to detect and characterize factors causing material failures. The authors' discussion is based upon work directed by the Air Force Materials Laboratory and is of a practical nature. This informative paper should be useful to those persons involved in non-destructive testing of materials as well as those wishing to learn of recent research and developments in the field of reentry systems.

R70-15243 ASQC 840; 341; 353; 720; 730

RECOMMENDATIONS FOR CORRECTIVE ACTION SYSTEMS

A. P. Alaimo (General Dynamics Corp., Quality Assurance Electronics Div., Rochester, N.Y.) *In: American Society for Quality Control, Annual Technical Conference, Transactions, 24th, Pittsburgh, May 11-13, 1970* Milwaukee American Society for Quality Control, Inc. 1970 p 31-37 1 ref
(A70-31102) Avail: $13.00

This document outlines recommendations for a Corrective Action system. The recommendations provide for the identification, control, and resolution of manufacturing problems, engineering problems, and vendor problems which result in product defects and failures. The basic objectives of a Corrective Action system are to identify problems and their causes, assign responsibility for initiating Corrective Action, assure timely action to eliminate the causes of problems, determine effectiveness of actions taken, and reduce production costs. Author (IAA)

Review: This paper is almost a checklist of things to be concerned about in a corrective action system. Its terse style makes it more useful for that purpose. It is generally a good paper and is rather complete. Some of the recommendations are overly categorical but when viewed in the light of the checklist are quite reasonable; that is, if one does not wish to follow the author's recommendation, he should have studied the system enough to know why he is not following it and to recognize the tradeoffs involved. The author points out that the reporting program is the most expensive portion of a corrective action system. It is not only that, however, it is at the very heart of the system and many papers have been written which show a "best" way of handling the reporting. One of the biggest difficulties is designing the form such that it encourages honesty and accuracy on the part of the person filling it out. Some of the author's points with regard to the data can be summarized in the two phrases, "Don't take the data unless you intend to look at them," and "Don't look at them unless you intend to do something about them." This will be a valuable reference paper for those who are concerned with evaluating or setting up a corrective action system. The reference cited by the author is essentially a private one and is not publicly available.

R70-15247 ASQC 844; 763; 775

VISUAL INSPECTION OF INTEGRATED CIRCUIT DEFECTS ENHANCED OPTICALLY

Robert L. Beadles (Research Triangle Institute, Research Triangle Park, N.C.) *In: American Society for Quality Control, Annual Technical Conference Transactions, 24th, Pittsburgh, May 11-13, 1970* Milwaukee American Society for Quality Control, Inc. 1970 p 153-160
(Contract F29601-69-C-0147)
Avail: $13.00

A spatial filtering technique, using laser illumination, was studied to determine its effectiveness in improving the visual inspection of integrated circuits (ICs). The optical filtering theory is given, along with some experimental results. It was concluded that spatial filtering to produce an IC defect image has considerable potential for effectively enhancing the capability of a human inspector in the visual inspection of integrated circuits. Author

Review: This paper deals with an important topic, namely, the visual inspection of integrated circuits. The first part of the paper which gives the theory is simple in principle, but many reliability engineers will have forgotten both the mathematics and the

optics required to understand it. Fortunately, an understanding of the theory is not necessary for an appreciation of what the technique can do. The paper explains the technique as well as can be done in such a short space. However, if this is the first time a reliability engineer has run across it, it is not likely to be clear to him. The pictures are an important part of the paper, but they are not reproduced well enough to show all of the desired features. For example, in Figure 5, it is not clear what defects have been enhanced. Figures 8 and 9 are somewhat more clear. Presumably, the ultimate purpose of such a filtering system would be to show only the defects and none of the circuit. Defect enhancement, as the author is suggesting, is a better description of what is actually going on. Presumably the illustrations in this article are not the best that will be achievable when the research has been completed.

R70-15257 ASQC 840; 851; 870

SYSTEMS EFFECTIVENESS: THEORY AND PRACTICE

Leo A. Aroian (Union College, Industrial Administration, Schenectady, N. Y.) *In: American Society for Quality Control, Annual Technical Conference, Transactions, 24th, Pittsburgh, May 11–13, 1970* Milwaukee American Society for Quality Control, Inc. 1970 p 355-366 22 refs

(A70-31112) Avail: $13.00

Examination of the theory and practice of the system effectiveness, its implementation and some examples of its performance. System effectiveness is equated to a function of performance, availability, reliability, maintainability, quality control, and manufacturing. It is stated that the effectiveness of the system, once defined, must be optimized, if possible, under the desired mode of operation and all possible alternative modes of operation of the system. IAA

Review: This paper does not limit its use of the term *system effectiveness* to its jargon sense within the reliability discipline, but rather uses it in several ways, one of which is its lay sense of wanting a system to be effective. The author has elsewhere stated that the emphasis of the paper is on his definition of performance which is new and essential in system effectiveness theory. There is considerable and worthwhile emphasis on an analysis of errors and uncertainties in the system and the discussion covers such other things as reliability, life testing, quality control, and maintainability. It does not seem to be a clear-cut, step-by-step presentation such as would be suitable for the beginner but is more like having a conversation with the author in which he explains his experience and gives practical advice to a person in the business on what he should be doing and not doing. It is the kind of paper that some readers will find very helpful, yet will not appeal to others. Those who know the author will find that the paper is written in his informal conversational style.

R70-15265 ASQC 844; 341; 730

QUALITY INFORMATION AS APPLIED TO THE SATURN S-II STAGE

Ralph L. Eaglen (North American Rockwell Corp., Quality and Reliability Assurance, Downey Calif.) and Emmett C. Edwards (North American Rockwell Corp., Quality Engineering and Information, Downey, Calif.) *In: American Society for Quality Control, Annual Technical Conference, Transactions, 24th, Pittsburgh, May 11–13, 1970* Milwaukee American Society for Quality Control, Inc. 1970 p 499-503 Avail: $13.00

Outline of the Quality Information System implemented for the Saturn S-II Program for assurance that quality data requirements are maintained. The data systems consist of a series of 'closed-loop' input/feed-back methods which are designed to assure that design requirements are totally incorporated into the hardware and software products. Quality Assurance personnel are involved in each phase of operations from release of design requirements through vehicle launch activities. Data accumulation and assessment at various phases of product fabrication and test activities and quality trends reflecting performance levels provide the basic controls essential for maintaining maximum quality standards. IAA

Review: This paper appears to have two purposes. The first is to get into a public record the kind of activities of the quality information group, and the second is to provide people who are in the same business an opportunity to compare their nominal systems. There is little for a reviewer to dispute in a paper such as this, since the system is so large and complex that any description of it is necessarily incomplete, and any analysis of a complete description is a long-time project, not a short review. The paper gives no indication of the amount of extra time and effort consumed by the system of reporting and information (this is regardless of how necessary such time and effort are), and thus it will be difficult for those not in the same field to get an idea whether similar systems would be useful in one's own different application.

R70-15266 ASQC 844

REDUCTION OF FRICTIONAL-CORROSION EFFECT ON FATIGUE

V. Yu. Vakhtel *Russian Engineering Journal*, vol. 49, no. 2, 1969 p 16-17 2 refs

To reduce stress concentration in components, a method is proposed whereby a network of grooves is made in the surface to be protected. The grooves must be of sufficient depth, and are mainly at right angles to the principal stresses in the surface. To check the effectiveness of the technique, comparative endurance tests were made on a grooved bolted joint. The tests showed that grooving greatly reduced the rate of crack development, roughly trebling the fatigue life. When a coating of molybdenum disulfide was applied to the contact surface of the bolt, the number of loading cycles withstood by the bolt before it failed was nearly doubled compared with the original design. M.G.J.

Review: The translator has labeled the effect "frictional-corrosion" whereas the more usual term in this country is fretting-corrosion. It is an important consideration in many kinds of fatigue, and the author has a suggestion for mitigating its effects. While the technique is not emphasized in the American literature, it is difficult to say whether or not it is used in practice. It cannot be used on all types of fretting fatigue but seems to apply largely where the fretting occurs on surfaces that are carrying only very nominal loads (normal to the fretting surface). The principle is worthwhile remembering: under these circumstances if the fretting can be confined to areas wherein all the stresses are nominal (and the author does it by grooving a bolt), then the deleterious effects of fretting will not affect the fatigue life of the bolt. The drawing in Figure 2 seems self-contradictory and cross-section 2 appears to be much more what the author is describing rather than cross-section 1. Thus, glancing at this article can be of value to mechanical design engineers since it may give them ideas for improving the fatigue life of the machines they are designing.

R70-15273 ASQC 844; 815
Joint Inst. for Lab. Astrophysics, Boulder, Colo.
THE RELIABILITY OF PROPERTY DATA, OR, WHOSE GUESS SHALL WE USE
Lee J. Kieffer 1969 5 p Presented at Chem. Doc. Sessions, Middle Atlantic Regional Meeting (4th), ACS, Washington, D. C., 12–15 Feb. 1969 Submitted for publication
(Contract DA-31-124-ARO(D)-139)
(AD-698899; AROD-4445:146-P) Avail: CFSTI

Increased reliability of property data can be achieved by critical evaluation of the techniques used in making measurements. The necessity for and the implementation of such evaluations are explored. Author (TAB)

Review: While the main thrust of this paper is directed at scientific data, the situation is much worse in engineering data. Designers who wish to make reliable products look up characteristics of materials in handbook and supplier literature. They may even call out ASTM or other specifications to ensure that the material has certain properties. Handbook data are notorious for implying an accuracy much greater than really exists in such data and for not indicating the tremendous spreads which can often be found in them (in view of all the vagaries in real life from purchasing problems to shipping errors). The problem of reliable property data becomes more critical as designers use more complex models, use smaller factors of safety (or whatever they choose to call them), and in general try to strive for higher reliability by making more precise calculations. All too often, it is only the reliability of an irrelevant model that has been calculated; the reliability of the actual product will be much less, due in large part to the fact that the numbers to be plugged into the model were not typical of experience. Thus, reliability engineers should read this article, or at least be acquainted with the author's experience and conclusions, to realize that even "over there" in science (where things are done remarkably accurately) the practitioner is ordinarily very over-enthusiastic about the accuracy of his results. This over-enthusiasm of accuracy of models is prevalent in academic reliability efforts where attempts are being made to push the state of the art in reliability calculations.

R70-15277 ASQC 844; 782
Sandia Corp., Livermore, Calif.
LIGHTNING ENVIRONMENTS
W. F. Gordon Apr. 1969 35 p refs
(Contract AT(29-1)-789)
(N69-41275; PB-183837; SCL-DR-69-40) Avail: CFSTI

This report contains a basic description of lightning phenomena to assist system designers in (1) understanding the over-all environment, (2) identifying design strengths and weaknesses from a susceptibility standpoint, (3) viewing potential design problems in proper perspective, and (4) logically deriving an evaluation program with which to determine system transfer functions and ultimately susceptibility. The information is applicable to both safety and reliability design consideration. Lightning environments discussed include direct strikes to earth-based objects, direct strikes to airborne objects, and electromagnetic pulses from nearby strokes. Author (USGRDR)

Review: The design of a reliable system requires a thorough knowledge of the environment in which the system is expected to operate. This interesting report is intended for system designers who are concerned with both the reliability and safety of systems which are exposed to lightning. The author introduces system designers to both the qualitative and quantitative nature of lightning. The report is clear and well organized. The emphasis is placed upon reducing a system's susceptibility to lightning effects; however, the report is not meant to be a detailed treatment of the subject.

85 DEMONSTRATION/MEASUREMENT

R70-15220 ASQC 850; 773; 784
Hughes Aircraft Co., Fullerton, Calif. Ground Systems Group.
COMBINED ENVIRONMENT TEST FACILITY STUDY, PHASE 3 Final Report, 4 Mar.–4 Jun. 1969
Thomas B. Jones, Jr. 4 Jun. 1969 282 p
(Contract N00123-69-C-0066)
(AD-695844; FR-69-10-626) Avail: CFSTI

A design concept for a combined-environment test facility has been established. The facility provides a simulation of the USN fleet shipboard environment and is capable of being utilized to satisfy the test requirements of MIL-E-16400 (F), NAVY, for complete naval electronic systems. The test system can be deck mounted equipment or enclosed systems of 25,000 pound weight. The test chamber is 46' × 40'. The facility design represents the culmination of a study which included a literature search and trade-off analyses for various test system concepts. Author (TAB)

Review: The three reports contained in this document cover all three phases of an effort to develop a design for a test facility which uses combined environments in order to simulate shipboard environments. (Despite the title, Phase I and Phase II reports are contained in the same document as the Phase III report.) Together they provide comprehensive coverage of the effort from a survey of existing test facilities and capabilities to a detailed description of the design. They are well organized, well written and interesting. Even though they are oriented toward the problem of simulating shipboard environments, a wealth of information is given which will be useful for simulation of other operational environments. Many references on environments and environmental simulation are given in the Phase I and II reports. In spite of all that has been written on the subject, it is still not known whether the benefits of combined environmental testing (i.e., simultaneous simulation of multiple environmental factors) truly outweigh the costs. This report does not resolve the question, but it does identify the advantages. Disclosure of modes of failure caused by synergistic effects is the most frequently cited advantage in the general literature, but this alone may hardly be adequate justification in all cases. However, as the report notes, significant time and cost savings can also result from test planning and test operation. Also, the increased engineering confidence derived from the realism of test environments is one of the biggest plus factors for combined testing. Certainly if this confidence is needed and if the realistic environments can be generated with such a facility at lower costs than they could in the actual environment (as probably is the case for shipboard equipments), then the cost of such a facility is justified. The author in a private communication has emphasized the fact that the study was performed primarily to ascertain the feasibility of a combined environment test facility and that the conclusions were that such a facility was indeed feasible and practical.

R70-15225 ASQC 851; 761; 762
THE USE OF PROCESS CONTROL DATA IN ACCEPTANCE PROCEDURES FOR HIGH RELIABILITY COMPONENTS

B. H. Nichols (Welwyn Electric, Ltd., Bedlington, Northumberland, England) *(Scientific Society for Telecommunication, Symposium on Reliability in Electronics, 2nd, Proceedings, vol. C, Oct. 15-18, 1968 p 318-1 to 318-5, 318-A to 318-F Budapest Omkdk 1968)* *Electronic Components,* Jun. 1969 p 705-708

Discussion of a practical approach to the problem of how the user of electronic components, in conjunction with the supplier, may ensure that the units he is receiving are likely to have a high reliability. For optimum reliability at an economic cost, it is important that the user identifies both the components and the stress or environment that contribute most to the reliability problem. Otherwise, if reliability requirements under extreme stress conditions are applied equally to all components in the circuit, the total cost of the equipment would be prohibitive. I.A.A.

Review: In the beginning of this paper, the author points out that he does not deal with the esoteric, sophisticated mathematics of reliability and redundancy but dwells instead on some very practical considerations of assessing the quality and reliability of components. His suggestion is a very practical one and might even be considered mundane by some; namely, that (if the manufacturer will allow) he obtain access to the quality control information generated during production. He gives several examples of using this information in various ways. The author's main point is not that he is trying to introduce a new technique or tell people things they do not already know, but to encourage them actually to use this method. He has observed (apparently correctly) that very few specifications are based on such knowledge and that engineers, if given the knowledge, would use it, but they rarely seek it out. The idea is good and is recommended to all engaged in the reliability business. It is occasionally used in some situations wherein product with a low yield is not accepted, only product with a high yield is accepted (the basis stated by the author is used: if there is a low yield, there is too great a likelihood that bad units are slipping by).

R70-15228 ASQC 851; 766; 871

EVALUATE EQUIPMENT CONDITION BY FIELD INSPECTION AND TESTS

G. Kobrin (E. I. du Pont de Nemours and Co., Inc., Beaumont, Tex.) *Hydrocarbon Processing,* vol. 49, no. 1 Jan. 1970 p 115-120

Field equipment inspection and corrosion tests help keep process units operating with minimum maintenance. The following inspection and test methods, supported by case histories, show how inspection can be successful in the field: (1) visual inspection; (2) ultrasonic tests; (3) eddy current inspection; (4) radiography; (5) leak detection; (6) hydrostatic testing; (7) field corrosion tests; (8) miniature test heat exchangers. A.L.

Review: This paper is intended for persons concerned with the maintenance of process equipment such as piping, tanks, etc. The author's purpose is to stress the importance of field inspection and tests in reducing operating and maintenance problems. To accomplish this purpose, he presents a tutorial discussion of major inspection and testing methods and illustrates, through case histories their application to prevent premature failure and unscheduled shutdowns of process equipment. The reader should gain an insight into the state-of-the-art in this field. Although the title and introductory paragraphs do not appropriately describe the paper's contents, it is otherwise clearly written.

R70-15241 ASQC 851; 771; 830

THE TEST-DESIGN INTERFACE

Stephen F. Bleich (Singer-Librascope, Glendale, Calif.) *Space/Aeronautics,* vol. 53, no. 2 Feb. 1970 p 46-53
(A70-22678)

Discussion of the interrelation between design and testing in the aerospace field, holding that the concept of a test-aided design which is as valid and useful as the concept of a computer-aided design can be realized when testing is applied properly in aerospace designs. The frequent underestimation of the full value of the test function in the thinking of design engineers is noted as an obstacle to the implementation of testing procedures which interact with design functions rather than being merely go/no-go checks. Various examples are given in support of these contentions. Software problems of testing are considered as ones causing difficulties in the realization of design-aiding tests. IAA

Review: Testing accounts for a large portion of program budgets. It is therefore important to design efficient tests and to make the best use of test results. This paper is oriented toward managers concerned with aerospace testing; emphasis is placed upon environmental testing. The author is concerned that in almost every major aerospace program to date, there has been a major breakdown at the interface between design and testing laboratories. His objective is to dramatize the need for an effective test-design interface to accomplish this goal. He makes use of particular situations in past aerospace programs to illustrate problems that have occurred and the importance of the interplay between test and design laboratories. A concept that the author terms "test-aided design" is stressed. Test-aided design refers to the proper use of test results to determine the cause of failure and to provide guidelines for redesign. It will be worthwhile for managers engaged in either testing or design to read this article.

R70-15254 ASQC 851; 844

HOW RELIABLE IS RELIABILITY

Egon Loeckel (Westinghouse Electric Corp., Quality Control and Product Reliability, Laundry Equipment Div., Mansfield, Ohio) *In: American Society for Quality Control, Annual Technical Conference, Transactions, 24th, Pittsburgh, May 11–13, 1970* Milwaukee American Society for Quality Control, Inc. 1970 p 331-339
Avail: $13.00

The quality control function is outlined, whereby a statistical control on the assembly process is set up by listing all the inspecting and test functions and setting up a demerit point system for each. Details are also given on a reliability test program designed to assure customer satisfaction. Among the factors considered are the following: (1) Make certain that all conditions to which the product might be subjected are included in the reliability program, (2) Don't underestimate the value of common sense in judging the operation of the product and in making visual inspections. (3) Enter sufficient test performance data on the control charts so that decisions can be made. It is concluded that such a program results in improved product reliability, customer image, and profits. M.G.J.

Review: The title of this paper is somewhat misleading since the paper actually deals with product testing. It is specifically addressed to consumer product testing, but the principles, of course, will hold anywhere. The paper discusses the kinds of details to which one must pay attention and how one should go about the product when it is used properly but also with how it will behave when used improperly. The paper will be of primary

benefit to those engaged in the testing of consumer appliances but, as mentioned above, the principles are applicable in almost any industry.

R70-15268 ASQC 851; 844

NARROW BAND RANDOM FATIGUE TESTING WITH AMSLER VIBROPHORE MACHINES

D. J. White and J. Lewszuk (English Electric Co., Ltd., Mechanical Engineering Labs., Stress Analysis Section, Whetstone, Leicester, England) *Journal of Mechanical Engineering Science,* vol. 11, no. 6, 1969 p 598-604 15 refs

(A70-15887)

Description of modifications made to Amsler Vibrophore machines to permit narrow-band random fatigue tests to be made. In this mode of operation, the machine electromagnet is excited by means of a random generator, and a complete control loop is effected by connecting the output of the inductive transducer of the machine dynamometer to the automatic output regulator (compressor circuit) of the random generator. The dynamometer was strain-guaged and calibrated to read rms load. Under compressor circuit control, the stress peaks in a specimen followed the Rayleigh distribution at least up to four times the rms value. As in constant amplitude sinusoidal loading, these machines are capable of applying mean stress when working in random loading. Some practically occurring stress spectra may be synthesized by applying sequences consisting of a number of stepped rms loads, each step being applied for a predetermined time. IAA

Review: Fatigue is an extremely important failure mode in aerospace structures as well as many other mechanical devices. The traditional S-N diagram (introduced by Wohler himself and adapted a countless number of times since to improve its applicability to modern calculation requirements) is giving way somewhat to the concept of random fatigue. The advances in mathematical statistics have made the analysis of random fatigue more tractable and experiences in many fields have demonstrated its worth. This paper deals with both theory and application of narrow-band random fatigue. A practical problem is finding a machine that can be used for such tests, and this paper describes a modification of a standard fatigue machine. The paper serves another useful purpose in that it uses a minimum of jargon so that engineers or metallurgists who are interested in this field, but not completely versed in mathematical statistics, will be able to use this paper to educate themselves in random fatigue testing. Even in random fatigue, there remains the problem of cumulative damage. One hopes that the tractable methods will be much more realistic than, for example, the S-N diagram. One looks forward to the results in this area which the authors hope to get with this machine.

R70-15272 ASQC 851; 844

National Aeronautics and Space Administration. Goddard Space Flight Center, Greenbelt, Md.

NICKEL-CADMIUM BATTERY TEST PROJECT: RELATIONSHIP BETWEEN OPERATION, LIFE, AND FAILURE MECHANISM. VOLUME 3: ANALYSIS OF THE CELLS AND THEIR COMPONENTS

G. Halpert Mar. 1969 88 p refs

(N69-28089; NASA-TM-X-63550; X-735-69-25) Avail: CFSTI

Nickel-cadmium aerospace batteries were operated in different but related cycling schemes in an effort to relate cycle life to method of operation. When five of the ten cells in a battery failed, the remaining active cells were removed from test, the cell cans were opened, and the plates and separators were analyzed. The objective in performing a physical-chemical analysis on the cell materials was to determine what the long-term degradation processes were and whether they could be related to a specific type of operation. Visual examination, wet chemical techniques, instruments methods, and cell overdischarge and oxygen recombination tests employed in the analysis of the materials are described. The results indicate that, although there is wide variation in the materials, there was a general long-term mode of degradation common to all batteries regardless of operational scheme. The mechanism of failure involved the migration of electrolyte into the plates, the consequent drying-out of the separator, and the growth of negative active material through the separator. Author

Review: The paper reports an extension of a test program in an effort to provide that most valuable of reliability activities, "feedback for corrective action." The review, here, does not consider in detail the actual chemical and test methods but rather considers this effort from the reliability point of view. The results in the paper are of general interest, namely, that the degradation modes were relatively independent of the types of cycling to which the batteries were exposed. For many of the results, there is not a convenient descriptive model which can be derived on engineering/scientific grounds, and as the author points out, there are certainly none that can be hypothesized on statistical grounds. This report also implicitly typifies the practical difficulties one encounters in an application of physics-of-failure to a complex device. Many of the theories which have been developed and published about physics-of-failure completely fail to take into account such complications as are illustrated in this report. For example, there are numerous degradation modes; system components suffer many changes and it is not always clear whether a change should be labeled degradation or just a change. Thus, this report is valuable on two grounds: (1) the specific insights it provides in the case of these batteries and (2) providing academically oriented reliability people with a well-described case history which shows how complicated and uncertain many reliability investigations are.

R70-15274 ASQC 853

FAILURE REPORTING SYSTEM

T. David Kiang (Canadian Marconi Co., Arionics Reliability, Montreal, Canada) *International Electronics Conference and Exposition, Toronto, Oct. 6–8, 1969, Paper* 2 p

This failure reporting system provides an efficient flow of closed-loop failure information for a multiprogram oriented operation. The objectives are: (1) to satisfy the normal failure reporting requirements of military contracts; (2) to provide management visibility of failure activities to facilitate prompt and effective corrective action; and (3) to supply basic yield data for cost effectiveness analysis. Author

Review: A failure reporting system is necessary for the efficient collection and dissemination of failure information. This paper is intended for managers who are concerned with documenting failure data at various levels of functional testing. The author's purpose is to describe the operation of an automated failure reporting system with which he is familiar. The system's operation is described only briefly; however, the material can serve as a guideline in establishing such a system.

86 FIELD/CONSUMER ACTIVITY

No abstracts in this issue.

87 MAINTAINABILITY

No abstracts in this issue.

88 AVAILABILITY

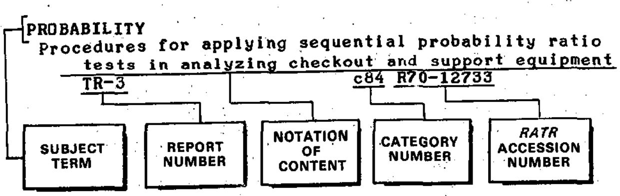
R70-15262 **ASQC 882**
AVAILABILITY ASSURANCE BY OPTIMAL SPARES SELECTION
H. R. Barton, Jr. and E. J. Westcott (RCA Corp., Defense Communications Systems Div., Camden, N. J.) *In: American Society for Quality Control, Annual Technical Conference, Transactions, 24th, Pittsburgh, May 11–13n 1970* Milwaukee American Society for Quality Control, Inc. 1970 p 413-424
(A70-31114) Avail: $13.00

Development of a spares allocation model for the optimal selection of sufficient spares to achieve a required spares protection level. The model assures allocation of spares in such a way as to meet a required probability that no failure will be unsupported by a spare during the replenishment period. Spares are assigned to maximize the increase in protection level per unit cost until the required protection level limit is met. Two variations of the model are developed. The first is intended for use where spares replenishment is essentially continual, as in a depot pipeline. The second variation is used with batch replenishment as with shipboard spares. The model has been applied to contract definition for estimation of the cost of spares, necessary in life-cycle costing. In engineering development, equipment definition is sufficiently well advanced to permit using model application as a basis for provisioning initial spares as well as writing spares requirements or coordinated ships allowance lists. The model has been programmed in FORTRAN for BTSS-RCA's time-sharing system for the Spectra 70 computer. IAA

Review: This paper describes a mathematical technique for adjusting the number of spares to maximize the availability. It is based largely on some mathematical approximations which are shown to be reasonably acceptable in most circumstances. The optimization technique is based on getting the maximum availability of the equipment (by manipulating the number of spares) for the minimum cost. A computer program is used for the calculations. The program itself is not given, but presumably can be obtained from the authors. It would be difficult to check the results, but the work appears to be competently done. The topic itself is essential for having equipment upon which one can depend. Before using the technique for any important calculations, one would have to have more information available about the nature of the approximations.

SUBJECT INDEX

Typical Subject Index Listing



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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS VOLUME 10 NUMBER 9

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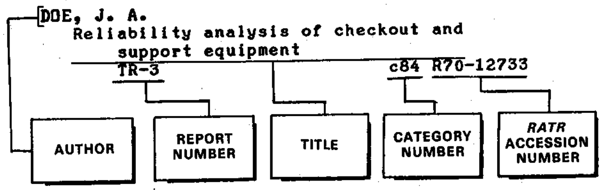

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RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS VOLUME 10 NUMBER 9

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Reliability Abstracts and Technical Reviews

OCTOBER 1970

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Number 10

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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The second section of *RATR* contains four indexes: The Subject Index is to assist in scanning or searching the literature on specific topics. The Personal Author Index identifies the publications of specific authors. The Report and Code Index is a listing of the report numbers of items abstracted and reviewed in the journal; this index also includes a listing of the ASQC codes for identifying the *RATR* accession numbers of the items to which the codes have been assigned. The Accession Number Index identifies the categories in which the abstract-reviews appear in the journal. Cumulative indexes are published annually.

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***RATR* ACCESSION NUMBER** · **TITLE** · **AUTHOR** · **CONTRACT OR GRANT** · **REPORT NUMBER** · **ASQC CODES** · **CORPORATE SOURCE** · **PUBLICATION DATE** · ***TAB* AND *STAR* ACCESSION NUMBERS** · **SALES AGENCY AND PRICE**

R70-12733 ASQC 844; 413
General Equipment Company, Banville, Calif.
RELIABILITY ANALYSIS OF CHECKOUT AND SUPPORT EQUIPMENT
John A. Doe 23 Sep. 1969 27 p refs
(Contract NAS15-13411)
(AD-629305; N69-15098; TR-3) Avail: CFSTI

***RATR* ACCESSION NUMBER** · **TITLE** · **JOURNAL REFERENCE** · **ASQC CODE** · **AUTHOR AND AFFILIATION** · ***IAA* ACCESSION NUMBER**

R70-12739 ASQC 814
SEMICONDUCTOR RELIABILITY
Joseph A. Smith (Eastern University, Arlington, Penn.)
Electric Journal, vol. 8, Apr. 1969, p 478–492.
(A69-12569)

***RATR* ACCESSION NUMBER** · **TITLE** · **CONFERENCE OR SYMPOSIUM REFERENCE** · ***IAA* ACCESSION NUMBER** · **ASQC CODES** · **AUTHORS AND AFFILIATIONS** · **AVAILABILITY AND PRICE**

R70-12765 ASQC 773; 221; 823
TESTS OF SYSTEMS WITH SOME DEPENDENT FAILURES
Joseph A. Smith (Eastern University, Arlington, Penn.) and B. James White (General Equipment Company, Banville, Calif.)
Association of Reliability Engineering, Failure Rate Conference, Olney, Tex., Mar. 13–17, 1969, 8 p. Available from Assoc. of Reliability Eng., New York: $1.00
(A69-12407)

VOLUME 10 NUMBER 10

Reliability Abstracts and Technical Reviews

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October 1970

80 RELIABILITY

R70-15318 ASQC 802
Army Materiel Command, Washington, D. C.
QUALITY ASSURANCE RELIABILITY HANDBOOK
Oct. 1968 444 p refs
(N70-74814; AD-702936; AMC-PAM-702-3)

The handbook is intended to serve as a guide for project and commodity managers and professional personnel in the planning, direction, and monitoring of reliability programs. The format is such that there are seven basic chapters with appendixes topically aligned to each. The material provides a simple, straightforward approach to the life cycle aspects of reliability. The appendixes contain technical discussions and mathematical treatments of techniques as they apply to the narrative in the chapters. Examples, applications, and solutions are included. Author

Review: This handbook has just recently become available through CFSTI. It is a surprisingly good treatment of the subject when one looks back on some handbooks and textbooks that have been produced. Even though the handbook is very large (over 400 pages) most of it is taken up with detailed appendices. This is good organization, especially since the book is written for managers, contract monitors, and other non-technical personnel. They can read the handbook itself, which consumes only 150 pages or so, and then look for any of the technical details which turn out to be important to them and which they do not know. In many ways, the handbook resembles an annotated checklist. The philosophy expressed in this checklist appears to be adequate. The handbook possesses both the advantages and the disadvantages of a checklist—the main disadvantage being that it requires a modest amount of interpretation and this may be done poorly by some users. The statistical content appears to have been written by a competent statistician; while it is easy for anyone to quibble with wording here or there of emphasis in the presentation, the overall job is good. There are some things a reader may wish to consider (especially if he is trying to get more from the document than was intended) when reading these appendices: (1) There are other kinds of redundancy than those mentioned; in particular, some circuits are not reducible to either series or parallel structures. They are often called *bridge* or *hammock* networks. (2) Even though much of the text cautions against the use of MTBF without stating the distribution in advance, many of the examples presume an exponential distribution and offer only hazard rates for components. (3) Hazard rate and failure rate are used interchangeably. (4) Some of the examples miss an opportunity to be quite practical; for example, in one reliability allocation situation, there are not enough data to perform one of the more complex analyses involving dynamic programming, so some parametric forms are suggested for those data. A more practical thing to do would be to suggest some method of analysis which uses only those data which are available. It could then be refined if and when more data became available. These "quick and dirty" methods are very important since, in many situations, the data are not sufficient to justify any hypotheses which are more complex. (5) The discussion of goodness of fit of distributions to experimental data is the conventional one given in statistics textbooks and there is nothing wrong with it in terms of the mathematics/statistics. As a practical matter, the power of the test varies widely with the amount of data. When there are very few data, almost any hypothesis can be accepted. It there are enough of them, any hypothesis will be rejected. Therefore, one of the biggest determining factors in accepting or rejecting an hypothesis about goodness of fit is how many data there are. An important consideration is the use to which this distribution will be put. It it is for interpolation, and the uncertainties in the parameters of the distribution have been calculated, then if these uncertainties are expressed in any answer given by using the distribution, no harm will be done. In other circumstances, the ice is much thinner.

81 MANAGEMENT OF RELIABILITY FUNCTION

R70-15292 ASQC 810
QUALITY AND RELIABILITY: LET'S BETTER UNDERSTAND THEIR RESPECTIVE ROLES
Dennis L. Conley (General Electric Co., Apollo Systems Dept., Daytona Beach, Fla.) *Quality Assurance* May 1970 p 40-41

The point is made that understanding the intent of quality control and reliability engineering makes it simpler to define the relationships and pursuits of each entity. The emergence of reliability as a separate methodology within the aerospace industry is seen as the natural expansion of quality control procedures in general. Additional distinctions between the two concepts are

drawn by assigning reliability engineering's responsibilities to systems and design engineering, while attributing to quality control a concentration on production, test acceptance, installation, and service. Increasing awareness of the differences in reliability and quality has resulted not only in the growth of separate technologies for each but also in an understanding of how the two can complement and strengthen the role of each other. P.R.F.

Review This article deals with a subject which has been the source of controversy in the last decade or two. One of the big difficulties in discussing the relative roles of quality and reliability is that the two are not dichotomized easily. Neither of the two concepts is extremely well defined; each has many dimensions. The regions of overlap and mutual fuzziness are ubiquitous; for example, even in this paper, in one place the author points out how reliability can be considered a part of total quality control and then how quality control is essential for high reliability. One approach that often takes some of the controversy out of a discussion such as this is not to say, "this is what quality and reliability *are*," but rather to say that the author wishes to distinguish between the two in the indicated fashion. Perhaps managers will find the article of most interest in that it deals with administrative matters and the planning thereof.

R70-15309 ASQC 810
REMARKS
Earl C. Hedlund (USAF, Defense Supply Agency, Washington, D. C.) *American Society for Zero Defects, Annual National Symposium, 3rd, Anaheim, Calif., Apr. 6-8, 1970, Paper* 16 p

The need for quality control programs in the aerospace industry is seen as crucial to its survival and growth. Of the many possible variations in implementing the theory of participatory management, the one judged most valuable in meeting the industry's needs is the zero defects program. Special emphasis is placed on the importance of the individual's contribution not only to his own job, but also to the entire effort. The importance of management direction and its full support is explored as another factor contributing to the success of a zero defects program. Examples are cited of companies and industries which have reported substantial decreases in defects, increased efficiency, and reduced expenses after implementing this program. P.R.F.

Review: Motivational programs in reliability and quality control are important, although the degree of importance is somewhat controversial as judged from the literature. One of the big reasons for the controversy is pointed out in this paper, namely, that when management engages in them just for show, fails to put the real weight of top management behind them, or fails to realize that it applies to all workers including the professional and management staff, the programs have little or no effect. This paper is intended for managers who wish a background, a brief description, and some professional value judgments about zero defects. It provides this, along with good illustrations. The basic premise is developed that more top management involvement in the Zero Defects approach is required to provide a climate of participatory management. It is not enough to provide the employees proper working tools and working environment, as environment is not only physical but also psychological. Management must promote the generation of ideas and listen to the employee, as the worker is in the best position to effect the changes necessary to ensure that the job is done right the first time.

R70-15310 ASQC 810
QUALITY: THE CHALLENGE OF THE 70'S
T. C. Mc Dermott (North American Rockwell Corp., Quality Assurance, Autonetics Div., Anaheim, Calif.) *American Society for Zero Defects, Annual National Symposium, 3rd, Anaheim, Calif., Apr. 6-8, 1970, Paper* 10 p

The prediction is made that in the next decade, more time, energy, and resources will be devoted to change, and to keeping up with it, than in any comparable period in history. The rapid growth and expansion of technology, combined with the consumer movement toward quality, will demand the manufacture of better products at increased efficiency levels. An outline of the basic approach for achieving unprecedented quality standards is presented with applications to the aerospace industry in particular and to industry in general. Ultimate responsibility for product quality, however, is placed on the individual employee's performance, and it is suggested that management recognize and cultivate this most important factor in quality control. P.R.F.

Review: This author predicts improvements in quality and reliability in the coming years due to pressures from both government and consumer (these are not unrelated). Presumably, management will respond to these pressures due to the action of the marketplace and the government regulation. The talk is largely exhortative and non-technical. It is understandable by almost anyone regardless of his background in quality or reliability. It is addressed largely to managers who are not directly in the quality/reliability stream and is designed to encourage them to make high-reliability products a meaningful goal for their companies—one in which all of management from the top to the bottom will share in a positive way, even when the chips are down. The author has extensive experience in quality control and in the American Society for Quality Control.

R70-15311 ASQC 810
MOTIVATION AND THE ENGINEER/SCIENTIST
A. R. Tocco (TRW, Redondo Beach, Calif.) *American Society for Zero Defects, Annual National Symposium, 3rd, Anaheim, Calif., Apr. 6-8, 1970, Paper* 9 p

The lessons learned in developing and implementing a Zero Defects type program, called The Right Way, are reviewed as a basis for discussing a similar motivational program for engineers and scientists. It was realized that the technical staff does not respond well to the suggestion that they might benefit from a motivational program aimed at achieving excellence in personal performance, and that recognition must come in a professional form and bring with it the respect of peers. Therefore, a Performance Recognition Program for Engineering/Management personnel was designed to give special recognition to individuals who exhibited outstanding ability in the areas of technical achievement, budget control, and schedule performance. The criteria established for the selection process is given in detail. It is reported that positive results have been observed in the form of performance improvement since the inception of the program. M.G.J.

Review: This is a different kind of paper than one usually sees associated with "Zero Defects." After some introductory paragraphs on introducing a motivational program in a manufacturing area, the remainder of the paper deals with how this can be done with scientists and engineers. The author says this was a pioneering effort (they had only found one company there before them) and one which needed to be done. The reliability of an end product can be

greatly improved by making everyone in the company aware of his contributions to that reliability. The author goes into some detail on the program, giving charts and tables showing how various ratings are performed. The paper ought to be of considerable help to others who are considering establishing a similar program.

R70-15315 ASQC 810; 720

CLEANER AND CLEANING FOR COMPONENTS AND MICROELECTRONICS

Howard H. Manko (Alpha Metals, Inc., Research and Development, Jersey City, N. J.) *In: Proceedings of the 1970 20th Electronic Components Conference, May 13–15, 1970* Conference sponsored by the Electronic Industries Association and the Institute of Electrical and Electronic Engineers New York IEEE, Inc. 1970 p 129-133 2 refs

Avail: $10.00

After a brief introduction on the properties and effects of electronic dirt, the removal of contamination from assemblies is discussed. The use of liquids is considered to be the most efficient method of cleaning electronic equipment; dirts are therefore examined in relation to their solubility in cleaning fluids. Polar and non-polar solvents are defined, and the advantages and practicality of their use in different situations are analyzed. Special electronic grade cleaners, including bi-polar blends, are recommended, as solvent systems developed for other uses are not normally suitable for electronic hardware. Five major sources of contamination are listed, plus additional guiding factors for selecting the most suitable cleaning agent. P.R.F.

Review: This is a tutorial paper on the subject of cleaning. It will be of most benefit to those who are involved in high-reliability applications since this is where the difficult cleaning problems most often arise and where consequently the most precautions are often necessary. The article is a good one. There is some chemical jargon used, but its meaning is generally apparent from context and in any event can be skipped by the electronics engineer since if he follows the suggestions in the paper he will be getting help from chemists with his problem anyway. Those who are involved with the design and manufacture of highly reliable electronic equipment should be familiar with the ideas expressed in this paper. (The author mentions a forthcoming book of his own.) Cleaning these electronic devices is asserted to be a science; engineers should remember that it is also an art and perhaps most of all a trial and error situation (where one tries different kinds of solvents to see which is the most effective). This also requires means of observing contamination. As the author points out, observing such contamination is often difficult since it is rarely apparent to the eye.

R70-15321 ASQC 814

INFLUENCE OF RELIABILITY ON LIFE CYCLE COSTS

Allan Dushman (Dynamics Research Corp., Systems Analysis and Design Dept., Wilmington, Mass.) *American Society of Mechanical Engineers, Design Engineering Conference and Show, Chicago, May 11–14, 1970, Paper* 8 p 5 refs

(A70-33507; ASME Paper 70-DE-43) Avail: ASME: $1.00 members; $2.00 nonmembers

Development of a general model which can be used to study the tradeoff between increased reliability costs at the outset of a system's life cycle and decreased running costs for the remainder of the life cycle. From this model it is possible to determine the optimum failure rate, which minimizes the total life cycle cost. A numerical example is presented to illustrate the use of the model and to illustrate how the life cycle length and the various input costs affect the optimum failure rate and the life cycle cost. The time value of money is introduced into the model so that the effect of discounting the annual running costs can be evaluated. Author (IAA)

Review: This is a reasonable paper. A linear cost model has been assumed, viz., the costs add and are independent of each other except through the failure rate parameter and a few other parameters explicitly introduced. While anyone could argue with the detailed formulas on a nit-picking basis, it is not generally worthwhile to do so. For many companies, their cost formulation will not fit exactly this format anyway and the model introduced here will be used more in terms of guidelines than as something to copy exactly. It should be remembered by anyone using a technique such as this that the mathematics will yield a precise answer, but the real world is not modeled that well. For example, looking at the author's curves, a factor of 2 variation in λ will give roughly the same Life Cycle Cost within a few per cent (near the minimum point). Therefore, some measure of the width of the minimum should always be calculated. Very often within that width, factors which have not been included in the model will be of overriding importance and will determine where in that range one wishes to operate. Another point only briefly touched upon by the author is that many of the quantities are not known exactly; unfortunately, that is about as far as his analysis goes. One should probably plot the region of uncertainty (or some guess thereof) around each line. This further blurs the exactness of the minimum since now one is not even sure where the mathematical minimum comes. This very much widens the acceptable range of operation and again the exact operating point will ordinarily be determined by factors which were not included in the original mathematical models. It should be emphasized that not every activity which increases the reliability of the final system increases the cost thereof. Some, such as design reviews, may decrease the cost; others such as extensive reliability testing may more than pay for themselves by decreased warranty costs. The author has done a good job of running a sensitivity analysis on his equations to find the most important parameters. If one makes up a somewhat different equation, he should do the same thing. Those results will help in determining the various uncertainties in the desired operating point.

82 MATHEMATICAL THEORY OF RELIABILITY

R70-15283 ASQC 824

INFERENCE ON WEIBULL PERCENTILES AND SHAPE PARAMETER FROM MAXIMUM LIKELIHOOD ESTIMATES

John I. Mc Cool (SKF Industries, Inc., King of Prussia Pa.) (*American Statistical Association, Annual Convention, Pittsburgh, 1968.*) IEEE *Transactions on Reliability*, vol. R-19, no. 1 Feb. 1970 p 2-9 5 refs

Four functions of the maximum likelihood estimates of the Weibull shape parameter and any Weibull percentile are found. The sampling distributions are independent of the population parameters and depend only upon sample size and the degree of (Type II) censoring. These distributions, once determined by Monte Carlo methods, permit the testing of the following hypotheses: 1) that the Weibull shape parameter is equal to a specified value;

2) that a Weibull percentile is equal to a specified value; 3) that the shape parameters of two Weibull populations are equal; and 4) that a specified percentile of two Weibull populations are equal given that the shape parameters are. The OC curves of the various tests are shown to be readily computed. Author

Review: Estimation and inference for the Weibull distribution are receiving their share of attention in statistical and reliability literature. There is naturally a good deal of overlap in many of the papers; in this one the author has a footnote which states that while his was in the process of publication, another was published on one of the topics he has treated. This paper deals with the two-parameter distribution; the guarantee period is assumed to be zero. Many of the results are interesting to a statistically-inclined reliability engineer. Those who wish to apply them should see a companion paper by the author entitled "Evaluating Weibull endurance data by the method of maximum likelihood," which was presented as the ASLE/ASME Joint Lubrication Conference in Houston, Texas, 14–16 Oct. 69, and is scheduled for publication in the July 1970 issue of the ASLE Transactions. That paper was written for the practicing engineer and tabulates for many sample sizes of practical interest some percentage points of the author's random variables w, t, u, and v. Even though the author has shown that his functions are independent of the Weibull parameters, they are nevertheless very dependent on the sample size and the number of failures. (The times to failure are the random variables; the test is censored at the *rth* failure.) The method used by the author does not take into account some of his own results, namely, that the distribution is independent of the shape parameter. If one wishes to derive the algorithm for generating the distribution of v by using Equation 40, it helps to rederive that equation without using K_p and X_p, but using α instead. For practical purposes in Equation 40, the Q_i can be considered to be the log of the log of the reciprocal of a 'probability which is uniformly distributed.' Equation 40 is then solved, for example by Newton's method, for v and one point in the Monte Carlo procedure has been obtained. The author does not mention it, but the number of failures must be at least two; otherwise his proofs do not hold. An interesting result from the author's Figure 1 (CDF of v) is that for 5 failures in a sample of 10, the 80% symmetrical confidence interval for $\hat{\beta}/\beta$ is 0.8 to 3, which is quite an uncertainty.

R70-15284 ASQC 824

AN APPROACH TO THE MINIMIZATION OF MISCLASSIFICATION IN THE REPAIR OF EQUIPMENT

Alan J. Gross (California University, Center for Health Services Research, School of Public Health, Los Angeles) IEEE *Transactions on Reliability*, vol. R-19, no. 1 Feb. 1970 p 10-13 2 refs

A mathematical model is developed which accounts for two misclassification possibilities: the incorrect failure diagnosis of components, and the probability of removal of the system from service due to an oversight when such a removal is not justified. A procedure is given which minimizes the misclassification probabilities, contingent on a fixed amount of available capital for this purpose. The model is of the Markov type with the simplifying assumption of constant transition rates (over time) among the various states. Some examples are given. Author

Review: This paper uses straightforward statistical techniques to treat an interesting problem. The mathematics was checked and appears to be competent. The assumptions are clearly stated and should be read with care because any such mathematical development analyzes only the model defined by its assumptions, not some real-world problem. In using this method, probably the most difficult part will be in getting the cost functions for the various states and transitions. That is, the difficult part of the problem will not be the mathematical analysis but rather trying to transform the real-world situation into tractable mathematics.

R70-15285 ASQC 824; 433

A BAYESIAN APPROACH TO RELIABILITY ESTIMATION USING A LOSS FUNCTION

Ronald V. Canfield (Utah State University, Logan) IEEE *Transactions on Reliability*, vol. R-19, no. 1 Feb. 1970 p 13-16 3 refs

A Bayesian estimate of reliability for the exponential case is developed which utilizes the basic notion of loss in estimation theory. Since the loss associated with overestimation is usually greater than the loss associated with underestimation of reliability, the loss function can be a useful tool. The loss function and prior distribution of reliability presented are sufficiently flexible to be compatible with many situations in which reliability estimates are required. When no prior information is at hand and a symmetric loss is used, the resulting estimate is seen to be the minimum variance unbiased estimate of reliability. This agreement gives some credibility to the precision of the estimation approach. Author

Review: The primary contribution of this paper lies in the definition of the loss function used. Employing a lower confidence bound as an estimate of reliability, a loss function is found which has useful analytical properties. The loss function permits the analyst to designate the degree of nonsymmetry of loss. The discussion of the uniform prior distribution illustrates the difficulties involved in using this approach. As shown in the paper, the uniform distribution on reliability is not the same as the uniform distribution on hazard rate, and the engineer who does not know the answer in advance does not know which one "really" illustrates his ignorance. Therein lies the difficulty of application of some Bayesian methods when the random variable is continuous (when the variable is discrete, this problem does not arise). Many papers in the literature have endeavored to show what is the best distribution for representing on some function of the variable. Two common transformations are the variable itself and the logarithm of the variable. Another difficulty which is not brought out, but to which implicit reference is made, is the question of why a Bayesian approach which pushes to zero the engineer's previous knowledge is any better than classical approaches since they too presume that the engineer has no information other than that obtained from the sample under consideration. These are dilemmas which are encountered in most applications of Bayesian statistics, not this paper alone. In a private communication, the author has commented as follows: "... useful results may be found using a loss function and Bayesian methods which are not available by classical methods. If this is the case, the Bayesian approach is better by default. I believe that to be the case with this paper. I have not seen nor been able to derive by classical techniques an estimate of reliability which incorporates a meaningful loss function ..." The exposition in this paper is straightforward. The mathematics was checked and appears to be competent; reliability engineers can get some idea of the effect of nonsymmetrical loss functions and as long as they have some knowledge of statistics, the paper will be useful tutorially. The final formulas may be of direct use to those who are willing to designate a nonsymmetrical loss function. This is useful even if one is not sympathetic to Bayesian inference.

R70-15288 ASQC 824; 831

THE STATE VARIABLE APPROACH TO SYSTEM EFFECTIVENESS

Neil I. Heenan (MITRE Corp., Bedford, Mass.) IEEE *Transactions on Reliability*, vol. R-19, no. 1 Feb. 1970 p 24-32 1 ref

Expressions are given in the literature for the availability, mean-time-between-failures, mean uptime, and mean downtime for systems consisting of a number of identical modules in redundancy. Using the concept of superstates, vector expressions for these parameters are presented which apply to a system consisting of an arbitrary interconnection of different types of modules. A vector expression for system effectiveness is presented which is formally the same as the expression for availability in the case of a single-function system and which can be extended easily to cover multi-function systems. Author

Review: This is a good paper even though the author's intention to "... provide the reader with simple, easily remembered and readily usable expressions for the availability ..." will not be fulfilled for most reliability engineers. Only those with an extreme bent for mathematics and matrix notation will find them 'easy to remember' and 'readily usable.' Others will approach the subject somewhat more laboriously. The author has written elsewhere on this topic; see, for example, our review R69-14642. This paper appears to be a good summary of some of his earlier work. The paper can be followed by reliability engineers who are willing to apply themselves. The notation is explained reasonably well; the assumptions are clearly stated; and a numerical example is given to aid in interpretation. The author's conclusions are fulfilled: the paper does provide an elementary introduction to matrix analysis of reliability problems and does indicate how some of the important parameters of complicated systems can be determined readily from a matrix formulation of the problem in terms of the equations of state. The paper is recommended to reliability and design engineers who wish such a tutorial presentation.

R70-15291 ASQC 821; 831

SIGNIFICANCE OF EQUIPMENT RELIABILITY IN A TELEPHONE NETWORK

L. Lee (Northern Electric Labs., Ottawa, Ontario, Canada) IEEE *Transactions on Reliability*, vol. R-19, no. 1 Feb 1970 p 36-38 4 refs

A reliability concept is considered in which telephone traffic is taken into account for a telephone network. An analytic model of a simple network with parallel paths shows how telephone traffic is included in the telephone network reliability analysis. Examples are given to demonstrate the usefulness of this concept in the investigation of an optimum inspection policy for each path, and the effects of path age and failure rate on telephone network service. Author

Review: Even though this kind of calculation may be familiar to those in the telephone companies, it is not one that has appeared in the reliability literature. The derivation is rather straightforward, and several examples are given to illustrate the final formulas. The notation is explained reasonably well and the assumptions are stated clearly. Reliability engineers might find that this formulation of the problem will have uses in other places where two quite different kinds of failures can be experienced. The actual results are not particularly important in themselves, but are useful as illustrations of the method.

R70-15295 ASQC 824; 822

Western Ontario Univ., London. Carleton Univ., Ottawa (Ontario)

OPTIMUM QUANTILES FOR THE LINEAR ESTIMATION OF THE PARAMETERS OF THE EXTREME VALUE DISTRIBUTION IN COMPLETE AND CENSORED SAMPLES

Lai K. Chan and A. B. M. Lutful Kabir Repr. from Naval Research Logistics Quarterly, v. 16, no. 3, Sep. 1969 p 381-404 Sponsored in Part by National Research Council of Canada Prepared in Cooperation with Carleton Univ.

(AD-698969) Avail: CFSTI

The present study is concerned with the determination of a few observations from a sufficiently large complete or censored sample from the extreme value distribution with location and scale parameters mu and sigma, respectively, such that the asymptotically best linear unbiased estimators of the parameters in a paper by Ogawa (1951) yield high efficiencies among other choices of the same number of observations. (All efficiencies considered are relative to the Cramer-Rao lower bounds for regular unbiased estimators.) The study is on the asymptotic theory and under Type II censoring scheme. Author (USGRDR)

Review: This is a good paper, although its organization is such that it will be much more difficult for engineers to interpret than it will be for theoreticians to handle. For reliability engineers to make maximum use of the information, the tables along with appropriate cookbook procedures would have to be provided, with merely reference to the formal mathematical/statistical proofs. The Weibull distribution is an important one in reliability theory, both in terms of lifetime distribution and in terms of stress and strength distributions. Most often the samples are censored on the right and very often they are not large; therefore, attempts will be made to use these tables for as small sample sizes as the tables allow, regardless of any admonitions about asymptotic results in large-sample theory—the rationalization being that something is better than nothing. There is a very good list of references which the authors have keyed in well with the text and derivations and which are used to put the author's work in perspective.

R70-15297 ASQC 824

California Univ., Berkeley. Operations Research Center.

MODULES OF COHERENT SYSTEMS AND THEIR RELATIONSHIP TO BLOCKING SYSTEMS

Richard Butterworth May 1969 24 p refs

(Contract Nonr-3656(18); Grant NSF-GK-1684)

(N70-14832; AD-693968; ORC-69-11) Avail: CFSTI

Some known results concerning modules of coherent systems from reliability are given with new proofs. The relationship of coherent systems to blocking systems is pointed out, as well as an interpretation of modules for blocking systems. Author (TAB)

Review: This is a theoretical paper; the results are not accessible or useful to design and reliability engineers. The worth of a theoretical paper, however, is not to be judged by the number of immediate practical applications it produces. Mathematically, it is interesting; the author suggests some possible utility in developing further theory (theorems which might be useful in the methodology of making reliability calculations for systems). The report is a collection of theorems and proofs and will be useful largely to those engaged in this very theoretical part of reliability development. The foregoing is not to say that the work is unimportant; it is most useful in that it shows equivalence of two ways of looking at a system and in that it provides some theoretical insights.

R70-15299 ASQC 824; 822

Research Analysis Corp., McLean, Va.

ON ESTIMATION IN WEIBULL DISTRIBUTIONS WITH RANDOM SCALE PARAMETERS

Carl M. Harris and Nozer D. Singpurwalla Repr. From Naval Research Logistics Quarterly, v. 16, no. 3, Sep. 1969 p 405-410 refs Prepared in Cooperation with Hughes Aircraft Co., Fullerton, Calif.
(AD-698965) Avail: CFSTI

Work by the present authors on life distributions derived from stochastic hazard functions is related to certain articles by Cozzolino and Dubey. This relationship is illustrated. The emphasis of this article is upon problems of parameter estimation. USGRDR

Review: The Weibull distribution is very important in reliability, and the authors have related their work to various reliability estimation problems and put it in perspective to other similar work. This is a theoretical paper in that the organization is directed toward statisticians rather than, say, reliability engineers who would need cookbook procedures with only references to the proofs. As the authors mention, the emphasis in this paper is on estimating the parameters of the distribution from the set of data. There is nothing that indicates what the general shape of the Weibull distributions is, nor methods of ascertaining whether the sample can be reasonably expected to have come from such a distribution. (The authors' references 1, 2, and 4 were covered by R69-14658, R69-14602, and R69-14234.)

R70-15302 ASQC 824; 844
Grumman Aircraft Engineering Corp., Bethpage, N. Y.
PREDICTION OF STRESS AND FATIGUE LIFE OF ACOUSTICALLY-EXCITED AIRCRAFT STRUCTURES
Noe Arcas *In* NRL The Shock and Vibration Bull. 39, Part 3 Jan. 1969 (See N70-13621 03-32) p 87-97 refs
Avail: CFSTI

A technique for predicting stress on aircraft structure excited by high intensity noise is extended in several areas: (1) modal functions which provide improved boundary conditions are used; (2) further data is included in the comparison of theory and experiment; (3) statistical confidence limits are obtained for the predicted stresses; and (4) fatigue life predictions are made and the results are compared with experimental data. Author

Review: This is a good paper. The author appears to have been quite honest in the evaluation of his theory; for example, he points out that it shows up as the worst of the three that were compared. He does, of course, go on to point out how the evaluations of the other two might have been favorably biased. All in all, the situation is one which does inspire confidence in the author's work. Fatigue in aerospace structures, especially in jets, due to acoustically excited vibration, is very important. Since it is in the design phase where changes can be made most easily in the aircraft structure, estimations in that phase are very important even if the accuracy with which they can be made is poor. Anyone involved with acoustic fatigue should be familiar with the work in this paper.

R70-15305 ASQC 824
THE ESTIMATION OF RELIABILITY FROM STRESS-STRENGTH RELATIONSHIPS
J. D. Church (Kansas University) and Bernard Harris (Wisconsin University, Madison) *Technometrics*, vol. 12, no. 1 Feb. 1970 p 49-54 4 refs
(Contract DA-31-124-ARO-D-462)

The cumulative distribution functions F_X (x) and G_Y (y) are defined as the strength of a component and the stresses to which it is subjected. A discussion of a parametric solution to the problem of estimating reliability is then given, under the assumptions that the distribution of Y is known and that F_X (x) and G_Y (y) are both normally distributed; confidence intervals for P $\{Y<X\}$ are also obtained under these assumptions. The procedures are compared with another suggested by Z. Govindarajulu. Author

Review: This paper is the same as the one covered by R69-14436.

R70-15308 ASQC 824; 830
Air Force Systems Command, Wright-Patterson AFB, Ohio. Foreign Technology Div.
CERTAIN RELIABILITY PROBLEMS OF HOMOGENEOUS UNIVERSAL COMPUTERS
V. G. Khoroshevskii 17 Jul. 1969 22 p refs Transl. into ENGLISH from Vychisliter'naya Sistemy (USSR), no. 23, 1966 p 69-89
(N70-13614; AD-693840; FTD-HT-23-426-68) Avail: CFSTI

The basic reliability characteristics of a single computer and of a homogeneous universal computer system with reserve and recovery are considered. Their basic properties are determined: reliability functions, frequency of breakdown, average time of proper operation, degree of failure and recovery functions. Practical results obtained in verifying the reliability formulas for the Minsk-2 computer are described. Functions of readiness, reliability and recovery for universal computer systems with reserve and recovery are investigated. A general approach is developed for computing the reliability of such systems. The Erlang method is used to investigate several methods of restoring computer systems which are most frequently encountered in practice. Results of computing the readiness factor and evaluating the reliability functions as well as the recovery time for the Minsk-222 computer are presented. Author (TAB)

Review: This is an edited translation of Russian text which is oriented mainly toward theoreticians. The title is somewhat inappropriate since the paper illustrates the calculation of system readiness, reliability, and restoration for the case of an elementary machine and for homogeneous universal computers. The paper contains both theoretical equations and experimental results regarding pertinent reliability figures of merit. The paper is not easily readable and some of the equations are hardly legible.

R70-15319 ASQC 821; 540
Royal Aircraft Establishment, Farnborough (England).
PREDICTING THE BEHAVIOUR OF MATERIAL SYSTEMS BY FITTING A THEORETICAL MODEL TO OBSERVATION
P. H. H. Bishop and K. F. Roger Mar. 1968 28 p refs
(N70-17457; RAE-TR-69053) Copyright. Avail: CFSTI

In predicting the behavior of material systems, agreement between prediction and observation is frequently unsatisfactory even when an accurate theory is available, because values for some of the material constants are incorrectly assumed or not known. In these circumstances better predictions can be made by allowing the constants to take best-fit values between plausible limits. The method is discussed and experimental work described to confirm the accuracy of this type of prediction. Author (ESRO)

Review: This is a good report. The topic is important to many reliability engineers especially those who are concerned with calculations of reliability which involve materials' properties. Philosophically, the report treats the subject well; it is easy to infer at the beginning of the report that you will learn about the computer program the author has used; but this turns out not to be the case.

It is not necessary to use any particular method of curve fitting—least squares is the one ordinarily used—and since the report discusses fitting any kind of curve, obviously it must be an iterative solution since no general closed form exists. (There have been suggestions to improve the efficiency of iterative least squares procedures; namely, that the group of unknown parameters be divided into two parts, those capable of being calculated by the usual linear formulas and the others. One needs then to iterate only on the second group; those in the first group are calculated after the second are assumed.) It might also be possible to extend the mathematical complication and its utility by assuming a loss function in terms of the value for each of the parameters being estimated (confirmed), and the solution would try to minimize the loss function. This means that one need not set exact limits within which the parameter value must fall but could make the regions much more fuzzy. The discussions of curve fitting in general and extrapolation in particular are good. Much of the material will benefit those who wish to write semi-theoreticial and tutorial articles on how reliability engineers should use materials data.

R70-15320 ASQC 821
Naval Postgraduate School, Monterey, Calif.
PREDICTION OF STATISTICAL SYSTEM PERFORMANCE FROM PARAMETER DISTRIBUTIONS
Alvin La Vern Franson (M.S. Thesis) Jun 1969 65 p refs
(AD-703258) Avail: CFSTI

Techniques for extrapolating statistical data on the parameters of individual components to the statistical performance index for an overall system are considered. Two cases are evaluated: (1) The deterministic case in which the system's performance index is known functionally in terms of the system parameters. (2) The nondeterministic case in which only limited data on the performance index and its sensitivity with respect to system parameters is known. Computer programs are developed in both cases for combining given probability density distributions for the parameters into an overall probability density distribution for the system performance index. Theory and programs are developed and verified with a specific numerical example. Author (USGRDR)

Review: It is difficult to see wherein the contribution of this thesis lies. It uses extremely standard elementary probabilistic notions and likewise equally standard numerical integration techniques and combines them to evaluate probability functions of slightly complicated expressions. The reason people have not always used it is that the expressions can rather easily get much too complicated, or the functions may not exist in explicit form. When the functional relationships involved are implicit other techniques of numerical "integration" must be used and Monte Carlo is a favorite one. The paper is a good tutorial exposition of the combining of random variables and of numerical integration for anyone who wishes that kind of treatment. (On page 18, it is stated that B_X is a normal distribution. A more statistically accurate description is B_X is a random variable which is normally distributed.)

83 DESIGN

R70-15281 ASQC 837
ANALYSIS OF ELECTRONIC FUEL INJECTION
T. L. Rachel, R. G. Sauer, and L. E. Slimak (Bendix Corp., Detroit, Mich.) *Bendix Technical Journal*, vol. 2, no. 3 1969 p 36-45 6 refs

The reliability of electronic fuel injection for controlling the air/fuel ratio in internal combustion engines is analyzed in this paper. It is shown that parameter variations in the electronic fuel-injection system tend to misalign the actual value for this ratio from the optimum design-center value. The parameters in the fuel-transfer system that are most significant for the misalignment are isolated by means of computer analysis. Based on these and other parameters, the statistical properties of the air/fuel ratio are predicted. The substitution of specific parameter values into the general formulas developed confirms a correlation between the analytical results and experimental data. The analysis can be used as a tool for statistically designing an electronic fuel-injection system and also provides information concerning the component tolerances required to yield minimum emissions. Author

Review: Parameter variations analysis is often touted as an excellent way to achieve high reliability early in a design by pinpointing the effects that variations in the parameters will have on performance. It is often touted, but not nearly so often done. This report is a very good example of such an analysis. It has the additional advantage of being quite clear about the limitations of the model being used and of mentioning what the results do not show, as well as what they do show. Thus, the article can be of value to reliability engineers in general. It is, of course, of value to those engineers who are specifically interested in electronic fuel injection and the type of mechanism used for it.

R70-15287 ASQC 838
RELIABILITY ANALYSIS OF REDUNDANT NETWORKS USING FLOW GRAPHS
K. B. Misra and T. S. M. Rao (Roorkee University, Dept. of Electrical Engineering, Roorkee, India) IEEE *Transactions on Reliability*, vol. R-19, no. 1 Feb 1970 p 19-24 6 refs

A flow graph approach for reliability analysis is applied to redundancy with elements in the simple series-parallel networks and to the more general case with elements in non-series-parallel combinations. The reliability of networks for elements with open or short failures is analyzed with flow graphs. Typical examples are shown. Author

Review: The authors assert that their method of using flow graphs is one of the easiest ways to perform a reliability analysis of redundant networks, and their examples naturally enough bear this out. It is difficult to say how it will work on extremely complicated networks where there are various kinds of interactions and where elements are used in more than one function. Nevertheless, reliability engineers can improve their abilities by becoming familiar with flow graphs, and this paper illustrates their application. It does not go into any formal proofs. Naturally, one should check the assumptions being made (which are clearly stated in the paper) before presuming that the method is useful to solve his own problem.

R70-15290 ASQC 838; 821
RELIABILITY OF SYSTEMS WITH STANDBY COMPONENTS
J. Bush Jones (Computer Technology, Inc., Arlington, Tex.) IEEE *Transactions on Reliability*, vol. R-19, no. 1 Feb. 1970 p 35-36

A method is introduced for approximating the reliability of a large complex system with standby components. It is done by substituting an approximate simple model for the more complex system. Each part of the model has a simple formula for its reliability. Author

Review: This paper discusses an approximate kind of calculation for the reliability of a system which uses standby components and where the system is a relatively complex one. Unfortunately, the author says that an exhaustive error analysis is not feasible so that it is difficult to know just how far off one will be when using this approximation. The method has intuitive appeal, and it would help if even an approximate error method could be derived. (A line is missing in the second column on page 35. The author in a private communication has stated that the missing line should read as follows: "Of course, knowing the reliability of a component, it is possible to compute the failure rate if desired.") There has been some indication that this kind of approximation is fairly widespread, but here again is an example of one person's taking the initiative to publish it so that others may compare their usage with his to the benefit of the profession.

R70-15304 ASQC 831; 821
GERT, A USEFUL TECHNIQUE FOR ANALYZING RELIABILITY PROBLEMS
Gary E. Whitehouse (Lehigh University, Bethlehem, Pa.) *Technometrics*, vol. 12, no. 1 Feb. 1970 p 33-48 26 refs

Stochastic networks and GERT, in particular, are used to analyze reliability problems. The advantages of the method are found to be (a) the flexibility of the logical nodes available in GERT, (b) the magnitude of information available from the system such as conditional network probabilities and times, counts on elements in the network and renewal times on the elements in the network, and (c) the ability to model complex reliability problems. Author

Review: Graphical Evaluation and Review Technique (GERT), a technique for the analysis of stochastic networks, is discussed briefly in the first third of this paper, and the reader is referred to previous publications by the author and others for details. In the remainder of the paper, the author describes applications of GERT to the analysis of reliability problems, and emphasizes the advantages of the technique over the use of comparable flow graph models (for papers on flow graphs, see R63-10711, R64-11507, R66-12632, and R67-13205). The material is clearly presented and well documented. The paper is a worthwhile contribution to the literature on techniques available for modelling systems in order to analyze their reliability. Those who are concerned with the analysis of stochastic networks (which provide suitable models for many systems) will find this paper of value.

R70-15306 ASQC 830
Jet Propulsion Lab., Calif. Inst. of Tech., Pasadena. Guidance and Control Div.
DESIGN METHODS FOR FAULT-TOLERANT NAVIGATION COMPUTERS
Algirdas Avizienis 15 Oct. 1969 15 p refs
(Contract NAS7-100)
(N69-40894; NASA-CR-106409; JPL-TR-32-1409) Avail: CFSTI

Discussed is the problem of fault tolerance in digital computers with strong emphasis put on computers used in on-board navigation systems of aircraft and spacecraft. An extension of automatic maintenance to an entire navigation system is introduced. Two principal approaches to fault tolerance in navigation computers are analyzed. Examples are taken from recent aerospace computers, the Saturn V computer, and the Self Testing And Repairing spacecraft guidance computer. The problem of fault tolerance is identified and defined, and current applications of the computers are discussed. Some current exploratory research and research objectives for the future are described. Author

Review: This is a good paper which is meant for engineers involved in the design of fault-tolerant digital systems. Although the emphasis is upon navigation computers, the material presented has quite general application. The paper reviews the advantages and limitations of some of the more useful fault-tolerant techniques and introduces the reader to JPL's STAR (Self-Testing-and-Repairing) computer. The STAR computer employs a balanced mixture of fault-tolerant techniques to provide protection against the widest possible variety of faults. This easily readable paper is recommended for the novice as well as the more experienced engineer who wishes to gain an insight into the state-of-the-art in fault-tolerant system design.

R70-15312 ASQC 838
REDUNDANCY: USE WITH CAUTION
Norman E. Tipton (General Dynamics, Convair Div., San Diego, Calif.) *Quality Assurance* Feb. 1970 p 28-30

The point is made that the use of redundant elements may not always lead to an increase in reliability, and that the reverse can be the case if the redundancy is misapplied. To illustrate this, a hypothetical parachute system is presented. As several possible designs are considered, the probability of success changes; imposing different operating requirements on the same equipment necessitates a reevaluation of the components to be used as redundant elements. P.R.F.

Review: This paper illustrates some of the difficulties involved in the application of mathematical modelling to the real physical world. The author has picked an example in which an "improvement" is not an improvement and shows how to resolve the situation in this particular case. The author's calculations appear to be correct and his cautions are well directed. It might have been worthwhile, however, at the end to draw the more general conclusion for the reader, namely that there is a difference between a circuit diagram and a logic diagram and the concept of "being in parallel" can be quite different in the two kinds of diagrams. The author has treated a complex case which is often not considered in simple reliability explanations; namely, when there is not just one kind of operation but two, i.e., failure occurs when "it does when it shouldn't" or when "it doesn't when it should." It takes two logic diagrams to illustrate this problem, and whether one picks series or parallel circuit redundancy, in one of the logic diagrams the systems will be in parallel and in the other they will be in series. Therefore, the lessons to be learned from this example are (1) the descriptions of the electrical-circuit and the logic diagrams unfortunately use the same words but they are not the same diagrams; (2) when more than one logic diagram must be used to describe one circuit, the overall conclusions are not immediately obvious. It would have helped the article considerably if the readers could have been led to this conclusion by the text.

R70-15322 ASQC 837
MORE EXACT FORMULAE FOR LIMITING STRESSES AND FACTORS OF SAFETY
V. M. Kudryavstev et al *Russian Engineering Journal*, vol. 49, no. 5 1969 4 p 3 refs

Formulas for determining factors of safety are evaluated on the basis of known experimental data and test results. It is shown that it is necessary to limit the field of application of those formulas which have been derived from linear relationships for determining limiting stresses. Several examples are given to show deviation from the actual results. P.R.F.

Review: This paper will be of value to those who are doing research in fatigue rather than to designers and reliability engineers. It is concerned with the effect on fatigue life of varying the mean stress. The topic relates to the Goodman-type diagram which is found in this country. The authors are asserting that conventional practice in Russia is not substantiated by the data. Of special interest to readers in this country will be the data themselves and the kind of relationship they establish for a given life between the mean and alternating loads.

84 METHODS OF RELIABILITY ANALYSIS

R70-15280 ASQC 844
METHOD OF DETERMINING FATIGUE LIFE
E. A. Shur and S. A. Kolotushkin (The All-Union Scientific and Research Institute for Railroad Transport, Moscow, USSR) (*Zavodsaya Laboratoriya, vol. 35, no. 6, Jun. 1969 In Russian.) Industrial Laboratory,* Vol. 35, No. 6, p 871-873 Jun. 1969 p 728-730 3 refs

Description of a system for detecting transverse fatigue cracks during testing rails on a hydraulic machine. An ultrasonic method using surface waves was used to determine the initial time at which the fatigue cracks were formed. Three 18-mm diameter barium titanate piezoelectric crystals were attached to the rail head to detect transverse cracks formed during full-scale testing on rails without scratches. It is found that all the measuring should be carried out while the rail was under load, since detecting the fine cracks was difficult when the load was removed. A special automatic unit was installed for automatic control when pulsating unit was operating continuously throughout the day and night. It is found that the hardened rails have a distinct advantage over the rails not subjected to a heat treatment. IAA

Review: This paper is concerned with comparing materials on the basis of the amount of fatigue life left after a crack has been detected. This is an important consideration in many structures which are inspected on a periodic basis; if a crack is just too small to be detected on one inspection, one wishes the structure not to fail before the next inspection. While the paper is not entirely clear, perhaps due to translation difficulties, the authors have compared two kinds of steel rails on this basis. The details of mounting of the ultrasonic transducers, which are used to detect the crack and its size, are given along with a brief explanation of the procedure. Those engineers who are not familiar with a method of this type and who do have access to this translation ought to become familiar with the method.

R70-15282 ASQC 844
RELIABILITY AND DURABILITY OF AUTOMOTIVE FRICTION MATERIALS
W. M. Spurgeon and A. R. Spencer (Bendix Corp., Detroit, Mich.) *Bendix Technical Journal,* vol. 2, no. 3 1969 p 57-66 7 refs

The reliability and durability of one component of the automotive brake system, the friction material, is discussed in terms of survivorship curves. Reliability, devined as freedom from infant mortality and random failure, is found to be generally high. Infant mortality is rare because materials and processes are carefully controlled and final product inspection procedures are rigorous. Random failure is also rare, occurring ordinarily only under highly abrasive braking conditions. Durability and five types of wear mechanisms are discussed: thermal, abrasive, adhesion and tearing, fatigue, and macroshear. Quantitative studies of these mechanisms, with a view to the manufacture of friction materials having a longer service life, are now in progress. Author

Review: This article applies some of the concepts which were developed in reliability to automotive friction materials. These materials are often difficult to characterize completely. The five wear mechanisms (thermal, abrasive, adhesion and tearing, fatigue, and macroshear) are useful concepts and are not widely known by those who are not specialists in wear. Thus, the discussion is of value to many reliability engineers because they too have to deal with materials and systems which are rarely characterized as completely as one would wish. Physics of failure naturally receives a good deal of attention in the paper. Attention is directed to the engineering aspects of reliability as opposed to the statistical ones—and properly so. (In Figure 3 (a), the cross-hatched area can be misleading. The random failure region is a region on the abscissa—it has nothing to do with the orndinate—and lies between the intersections with the 0 line of the two curves. It is misleading to show this as an area since it is very easy for the uniformed to associate incorrectly the cross-hatched area with the number of failures or the probability of failure.) Not only is the material handled well from a reliability point of view, but the material is of high tutorial value to reliability engineers since it is rare that they will come across a good, easy-to-read discussion on it.

R70-15289 ASQC 844
AGING EFFECTS IN GOLD THERMOCOMPRESSION BONDS TO COMPLEX METALLIZATIONS
J. H. Anderson, Jr. (Rochester University, Rochester, N.Y.), W. P. Cox (Lockheed Palo Alto Research Lab., Palo Alto, Calif.) and T. Grant Maple IEEE *Transactions on Reliability,* vol. R-19, no. 1 Feb. 1970 p 32-34 7 refs

The times to failure to Au thermocompression bonds to Au-Mo-Al and to Au-Ti-Al multilayer films were determined as a function of temperature over the range of 125-400 C and compared with the time to failure of gold bonds to aluminum films. A 500-A Ti intermediate film was found to be ineffective as a barrier to reaction between gold and aluminum. On the other hand, a 500-A Mo film was effective, providing increased time to failure over that observed for bonds to Au-Ti-Al and Al films. No failures were observed after 2000 hours at 400 C when gold wire bonds were made to an Au/Mo/al metallization having 1000 A of molybdenum as the intermediate layer. Author

Review: This is a good physics-of-failure type paper. The experiments appear to have been quite worthwhile and to have been well performed and well analyzed. They are not, of course, an exhaustive treatment of the subject. As the authors mention, a large fraction of integrated circuit failures are attributable to the bonds and it behooves reliability engineers to be aware of what is going on in the bonding region. This paper extends that knowledge about two particular bonding systems. It should be remembered, or course, that some bonding systems are proprietary matters and, naturally, manufacturers using them generally extol the virtues of their systems and do not appreciate the vices being discussed. Thus, not all papers on bonding systems should be taken at their face value.

R70-15293 ASQC 844
WHY HIGH-TEMPERATURE PIPING FAILS
Helmut Thielsch (Grinnel Corp., Research and Development Div., Providence, R.I.) *Metals Engineering Quarterly*, vol. 10, no. 2 May 1970 p 7-11

It is asserted that all the reasons for the failure of high temperature piping fall into one or more of five classifications: design, materials, base metal defects, fabrication, and service conditions. Each category is analyzed in relation to its failure inducing potential; photographs of failures accompany each description. P.R.F.

Review: This paper deals with what reliability engineers like to call physics-of-failure; metallurgists, or course, have been involved in failure analysis long before that name became popular. This paper is largely a collection of photographs of failures and brief descriptions of the service history and the cause of failure. Most of the figures are reproduced quite well, although for many of them, some knowledge of metallurgy is essential for proper interpretation. Many aerospace systems contain piping; so this article will be of value to aerospace design and reliability engineers. As the author implicitly demonstrates in one of the cases, even though the correct materials are specified, wrong ones can be used. In some situations, it will be important in the manufacturing process to ensure that the proper materials have been used. These examples are in addition to those appearing in the author's book rather than being excerpts from the book. G

R70-15294 ASQC 844
Aeronautical Research Labs., Melbourne (Australia).
THE PROGRESSIVE MEASUREMENT OF LOCAL CREEP IN TURBINE BLADES
A. S. Finlay Mar. 1969 32 p refs
(N70-11160; ARL/ME-124) Avail: CFSTI

A method is presented for measuring the local creep strain in turbine blades. This method was successfully used to assess the remaining life of HS31 blades in a turbine, and to select the test temperatures to give a blade life of about 100 hours. Author

Review: This is a good short paper. It deals with an important topic and comes right to the point. The prediction of blade life is very important in turbines which in turn are an essential part of aerospace propulsion. The measuring of local creep as opposed to overall creep has important benefits in that it enables a much more fundamental analysis to be made. The method is quite simple in principle; one wonders why it was not done before (this is the case with many good ideas—they are obvious once someone thinks of them). There were no comparisons of the results here with those that would be obtained by static test specimens under similar conditions. One can think of many possible extensions of the testing method. The contribution of this paper is to show a test procedure which has turned out to be successful and helpful.

R70-15298 ASQC 844
Air Force Systems Command, Wright-Patterson AFB, Ohio. Foreign Technology Div.
METHODS OF DIAGNOSING FAILURE OF ANTI-FRICTION BEARINGS
A. I. Eroshkin et al 12 Nov. 1968 27 p refs Transl. Into ENGLISH from Sb. Statei Prochnost i Dinam. Aviats. Dvigatelei (Moscow), no. 4, 1966 p 214-230
(N69-26154; AD-683982; FTD-MT-24-312-68) Avail: CFSTI

A discussion of methods and for early detection of turbine engine bearing failure. Techniques mentioned involve analysis of metallic particles trapped in engine oil by various means, monitoring of the electrical resistance of bearings (as a means of determining continuity of oil film on friction surfaces), and spectrographic analysis of noises generated by bearings under different conditions. Equipment used is described and illustrated. Author (TAB)

Review: This is a surprisingly good paper, especially for a machine translation. Not only is the material of value to physics-of-failure analysts and failure-prevention engineers, but it is readable. Some of the electronic circuitry is out of date, but that portion of the detail is largely irrelevant. It is the discussion of what is happening to the bearings and of the detection procedures that is important. The authors' presentation of the ramifications of each procedure and detection mechanism is enlightening. Ball and roller bearings are very important in aerospace vehicles; thus, this report will be of value to aerospace reliability engineers.

R70-15301 ASQC 844
Boeing Co., Seattle, Wash. Office of International Operations.
STATE-OF-THE-ART AND FUTURE AIMS OF FATIGUE STRENGTH RESEARCH
Mar. 1969 90 p Transl. into ENGLISH from the German Rept. TB-80 Presented at the 30th LBF Anniv. Colloq., 27 May 1968
(N69-30338; F-259; TB-80) Avail: CFSTI

Methods of serviceability testing for determining aircraft life requirements are summarized. The objective of such tests is to establish fracture strength requirements of individual components under oscillating stress over the anticipated lifetime of the aircraft and to avoid over-dimensioning of these requirements. Serviceability values must therefore be geared to tolerable stresses in the individual case to the existing stress conditions and the structural conditions of the material, the component shape, and manufacturing side effects. The counting methods and analytical techniques used to characterize load-time functions are briefly described, and a short account of future directions in strength testing is given. Detailed discussions are also included for several special topics related to fatigue strength testing, load-time analysis, material selection, and lifetime evaluation. A.C.R.

Review: This is a collection of papers on fatigue which have been translated from the German; thus, it represents selected topics in the title rather than a complete survey of that subject. The papers appear to be very competent descriptions of each topic and include suggestions for further research. Unfortunately, the translation was made by someone who is not familiar with American terminology in fatigue and much of the nomenclature is strange. This means that only those who are fully conversant with the field of fatigue will find this material of value since they will so often have to interpolate a meaning in the sentence. There is a good emphsis on the stochastic nature of fatigue, especially in prediction of fatigue behavior. There are also some good discussions of random fatigue which is one of the important topics in fatigue research. While those doing extensive research (whether theoretical or experimental) in fatigue will find little that is new here, the topics are important and appear to be discussed by professionally competent people.

R70-15303 ASQC 844
INSULATION/CIRCUITS. DIRECTORY/ENCYCLOPEDIA ISSUE
Lincoln R. Samelson (ed.) Libertyville, Ill. Lake Publishing Corp. Jun./Jul. 1970 402 p

The handbook serves as a guide to reliability and design engineers in the construction of insulation systems. Divided into four basic sections, the handbook presents information on insulation concepts and functions, the application of insulation principles to electronic and electrical equipment, and the materials utilized in insulation systems. The fourth section contains directory listings where materials and services may be purchased. P.R.F.

Review: This entire issue is an encyclopedia of insulation procedures and materials accompanied by a directory on where materials and services may be purchased. Insulation is an extremely important topic for reliability and design engineers because the practical applications of insulators and insulating systems are not discussed in great detail in college courses—virtually all that one learns about it is on the job. This issue is largely tutorial; it does not pretend to advance the state of the art. The main section of Part A is "Insulation Concepts and Functions"; it discusses these quite well. Even though the word reliability is not mentioned, the probabilistic nature of the life of insulation systems is emphasized. It is a good introduction for anyone. It should be read in its entirety (it is not long), however, since from some of the early material it is easy to get wrong ideas unless the remainder of the material is also read. (This is especially true with regard to uncertainties in life.) Part B on application information has virtually no explicit discussion of reliability or life. The details that are presented are, or course, essential to a determination of those factors and many practical points are developed in these four sections. It is not mentioned anywhere in these articles, but the Arrhenius behavior for the acceleration of temperature effects at constant voltage is virtually always used. (Very often in the analysis, insufficient techniques are used, unfortunately.) Some sort of modified power law is most often used for the voltage behavior (the exponent is not a constant with voltage, which is where the modifications come in).

R70-15307 ASQC 844; 612

Joint Publications Research Service, Washington, D. C.

MICROCONTROL AND DIAGNOSIS OF MALFUNCTIONS IN DIGITAL COMPUTERS

A. F. Volkov et al 2 Oct. 1969 7 p refs Transl. into ENGLISH from Dokl. Akad. Nauk SSSR (Moscow), no. 4, 1969 p 750-753 (N69-39997; JPRS-48957) Avail: CFSTI

Programmed diagnostic checking for malfunctions in digital computers is discussed. Control structures of computers using combined macro- and microprogramming were compared. Results indicate that the advantages of the combined structure include high level automation, high degree of localization of failures, and good computational abilities. E.H.W.

Review: Achieving more reliable digital systems calls for the use of a balanced assortment of error detecting and correcting techniques. The purpose of this paper is to explore the potential of programmed methods for diagnostic checking in digital computers with combined control (both macro- and micro-control modes of operation). The authors lay the theoretical framework for the proposed method of fault diagnosis but do not consider in any detail the practical aspects of the scheme. In short, more supporting information is needed to convince the reader of the usefulness of the authors' technique. The paper is not difficult to follow and can be of interest primarily to theoreticians.

R70-15313 ASQC 844; 782

THERMAL PROBLEMS IN COMPONENTS

H. Mayr (Gruppe Componenti Elettronici (IEC), Milano, Italy) *In: Proceedings of the 1970 20th Electronic Components Conference, May 13–15, 1970* Conference sponsored by the Electronic Industries Association and the Institute of Electrical and Electronic Engineers New York IEEE, Inc. 1970 p 1-4

Avail: $10.00

After a consideration of the importance of temperature influence in components the heat transfer between heat dissipating components and their surrounding ambient is briefly analyzed. A description of the mechanisms of convection conduction and radiation is given, together with some practical data. The use of equivalent electrical networks for the solution of thermal problems is mentioned. The application of these considerations to design and testing of heat dissipating components is illustrated. Author

Review: This is a tutorial paper and serves that purpose reasonably well. In some instances, there are technical inaccuracies (they may not be important for engineering purposes): (1) The main one arises in using thermal resistance for transient heat flows. In the differential equation (sometimes referred to as Fick's Second Law) wherein the time derivative of temperature is directly proportional to the Laplacian of the temperature, the constant of proportionality is generally referred to as the diffusivity and it is not the same as the thermal resistance. It involves also the heat capacity and the density. Wherever transient heat effects are important, and this is especially true in the early consideration by the author of protecting a device from a temporary heat source, it is the diffusivity that must be considered and not the thermal resistance alone. (2) Conduction is asserted to take place usually only in solids; what the author means is that heat conduction is usually negligible in gases, not that it does not take place. Heat conduction may be more important than convection in some liquids under some circumstances. This is especially true when compared to solid insulators. (Anyone who has picked up something hot using a wet cloth as opposed to a dry one knows that water can be an extremely good conductor of heat.) Regardless of the above technical disputations, the article is a generally good discussion of heat transfer, although it does not have as practical an orientation in terms of giving numbers as might be inferred from the abstract. This kind of discussion appears from time to time in the literature. A much more practically oriented paper which gave engineering numbers a designer could use (in the absence of more exact information) was covered by R70-14872.

R70-15314 ASQC 844

RELIABILITY OF HYBRID MICROCIRCUITS IN USE TODAY

Robert J. Straub (General Motors Corp., AC Electronics Div., Milwaukee, Wis.) *In: Proceedings of the 1970 20th Electronic Components Conference, May 13–15, 1970* Conference sponsored by the Electronic Industries Association and the Institute of Electrical and Electronic Engineers New York IEEE, Inc. 1970 p 16-31 8 refs

Avail: $10.00

Results of testing nearly 125,000 hybrid microcircuits from eight manufacturers show the need for formal testing and screening to avoid potential quality and reliability problems. Information presented includes the test procedures imposed on the microcircuit suppliers before shipment, as well as those performed after delivery. Test data are summarized relative to receiving-inspection, sample inspection and environmental testing, extended performance testing, and subsequent assembly and field performance. The continued need for new evaluation techniques is further evidenced by results of stepped stress mechanical and environmental testing, performed per MIL-STD-883 on three different hybrid circuits from three manufacturers. Author

Review: A key message of this paper is that present manufacturing methods and quality control procedures for hybrid microcircuits are not yet mature enough to guarantee the performance demanded by contemporary military electronic systems. The paper summarizes the experience of a user in buying and testing more than 10 hybrid circuits from 1967 to early 1969. All vendors were required to inspect, test and condition their circuits to very demanding specifications prior to shipment. Even so, the user found he could reasonably reject small percentages of the product received (through his incoming inspection). The details of the test procedures and the specific failures noted constitute the text of this paper. No mention of cost appears, but these hybrids are of necessity costly because of the extensive testing. The performance of the units incorporated into field equipment has been good, however, and apparently justifies the cost. Hybrid microcircuitry at present uses bonded chips intraconnected by wires, thus multiplying the failure-prone lead attachment problems encountered with integrated circuits. This paper gives insight into the magnitude of the problem as well as the effort required to eliminate such failures. The quality of the photomicrographs used in the paper is poor; it is barely possible to "note the unacceptable crossovers of internal conductors" as suggested in the caption of Figure 1. The first paragraph of the paper is an illustration of poor technical writing and should be omitted. Fortunately, the rest of the paper is more concise and readable.

R70-15316 ASQC 844

MECHANISM OF FAILURE IN HIGH VOLTAGE MICA PAPER CAPACITORS

J. Burnham and R. S. Buritz (Hughes Aircraft Co., Research and Development Div., Components Dept., Culver City, Calif.) *In: Proceedings of the 1970 20th Electronic Components Conference, May 13–15, 1970* Conference sponsored by the Electronic Industries Association and the Institute of Electrical and Electronic Engineers New York IEEE, Inc. p 419-431 2 refs

Avail: $10.00

Based on the idea that reconstituted mica paper without an organic binder would be equally as good as split mica insulation in resisting degradation from ac corona, a study has been made of the ac corona degradation of these capacitors impregnated with resin. The results show that corona is initiated at relatively low stresses. Two types of corona degradation were observed: a localized decomposition resulting in puncture of the dialectric; and a general degradation occurring in a multiplicity of spots and covering a total area of one square centimeter. Corona inception voltage measurements detected the presence of internal space-charge layers. A very great difference was observed between the stress at which dc and ac corona is observed. The lifetime for varying ac stress was determined for two dialectric thicknesses. Author

Review: This is a good detailed paper on the failure mechanisms in mica-paper capacitors. It is an excellent example of what is often called physics-of-failure. There is no real happy ending to the paper, i.e., the authors have not shown how to eliminate all the problems. What they have done, however, is (1) to identify clearly the mechanisms of degradation and failure and to show that it is not attributable to the free ions from the potting resins and (2) to identify AC corona as the primary degradation and failure mode and the ten-to-one increase in corona inception voltage between resin-impregnated and oil-impregnated capacitors. The paper will be of value to reliability engineers who are interested in the techniques that were used and to users and manufacturers of the mica-paper capacitors. It is interesting to note that this paper was written by a user, not a producer, of the capacitors.

R70-15317 ASQC 844

Columbia Univ., New York. Henry Krumb School of Mines.

A SYSTEMATIC STUDY OF FATIGUE MECHANISMS IN IRON Interim Technical Report

Hormazdyar Minocher Dalal (Ph.D. Thesis) May 1969 75 p refs (Contract DA-31-124-ARO(D)-382)
(N70-26103; AD-700174; AROD-5642-5-MC)
Avail: CFSTI

Monocrystals and polycrystals of Ferrovac E iron were subjected to pull-release fatigue cycles of constant load amplitudes. Luders band velocity was measured under cyclic stress conditions. Cyclic creep measurements were done at low temperatures. At low stress amplitudes, the cyclic creep rate could be made to vanish by stress cycling. At this stage the applied stress amplitude equals the internal stress, so the effective stress could be determined. It has been shown that the mobile dislocation density remains constant throughout the fatigue life of a specimen. On the basis of dislocation dynamics, a cyclic strain rate equation has been derived and experimentally verified. The characteristic rapid and saturation hardening stages have been shown to be a result of the dislocation multiplication rate obeying a first order kinetics in multiplication and a second order kinetics in dynamic recovery. Author (TAB)

Review: This report is essentially a Ph.D. thesis. It combines experimental and theoretical analysis of fatigue in relatively pure iron (not steel). The author asserts that the theory can be made to fit the experimental results quite well. It is not entirely clear that all of the experimental results are his own, since in at least one place, the minimum loading is the yield strength and the maximum loading is the tensile yield strength. Apparently, the specimens were unnotched; the experimental results are useful for checking the theory, not for any practical design purposes. Therefore, this paper will interest those doing research in fatigue rather than aerospace design and reliability engineers. This report does have the potential for increasing our understanding of the fatigue phenomenon. As the author points out, it is concerned with a micro-understanding of fatigue as opposed to a macro-understanding. It is a rather short thesis and, as befits such a scholarly document, there are many references for those who wish to study the material in detail.

R70-15323 ASQC 844

FAILURE MODE ANALYSIS: AN APPROACH TO RELIABILITY PREDICTION

W. Taylor (Westinghouse Electric Corp., Ocean Research and Engineering Center, Underseas Div., Annapolis, Md.) *Quality Assurance*, vol. 9, no. 1 Jan. 1970 p 60-61

A failure mode analysis of a system is defined as an analysis of its constituent components to determine which of the component failure modes will likely cause the system to fail. To illustrate the difference between a failure mode and a failure mechanism, an example of a capacitor failure is given. It is noted that, since each component is a potential failure, to achieve maximum effectiveness of the analysis all critical failure modes of the components must be identified. An example, accompanied by a circuit diagram, explains how failure mode analysis works; it is then suggested that this method be utilized when test equipment is used to check out a missile or weapon prior to its launch. P.R.F.

Review: This is a rather shallow article (perhaps because of its being so short), not because it is elementary or is designed only to arouse the readers' interest but shallow because anyone who tries to push it further than that, runs into difficulties, e.g., when an intelligent reader's interest is aroused, he runs into trouble trying to pursue the author's examples and points. It deals with an impor-

tant topic (failure mode analysis)—one to which designers should pay attention. The analysis is often called *failure modes and effects* analysis and sometimes even *failure modes, effects, and criticality* analysis. The difference between these is well illustrated by the author's example. He has a diode across a coil and comes to the conclusion that if the diode opens, it does nothing detrimental to the failure rates; if it shorts, it kills the circuit. The latter part is quite true, but if the former is true, namely, opening does no damage, then of course there is no reason for it to be there in the first place—the circuit could be improved by removing it. The failure effect of an open is the lack of spark suppression on the coil and the consequent damage to the contacts which actuated that coil. Criticality goes one step further and decides how critical this sparking is with regard to the success of the mission. Essentially, all the author has done is to suggest that failure rates for parts should be broken down into their failure modes. This is good (but not new) advice; unfortunately, most often this extra information is not available. Another example of shallowness is the statement ". . . to enhance reliability, lower failure rates and raise the equipment's MTBF." Those three phrases, of course, all mean essentially the same thing. The author also distinguishes between failure modes and failure mechanisms, but the distinction between modes and mechanisms here is like the distinction between strategy and tactics, and it is well to remember that the colonel's tactics are the lieutenant's strategy; i.e., there is no absolute description, only a relative one. In the subheading for the title, 'average operating time between failure' is used in one case and 'mean-time-between-failures' is used in another. It would have been much better to use the same expression in both places and they would differ only by the modifier—in one case, it would be 'observed' and in the other case 'predicted.' All in all, the paper contains little that is actually wrong. The information in it is all right, but since communication involves what people do not say as well as what they do say, it might be easy for a beginner to be misled.

R70-15324 ASQC 844; 820

A NEW CORRELATION OF LOW-CYCLE FATIGUE DATA INVOLVING HOLD PERIODS

J. B. Conway (General Electric Co., Nuclear Systems Programs, Materials Evaluation, Cincinnati, Ohio) and J. T. Berling (General Electric Co., Nuclear Systems Programs, Applied Mechanics, Cincinnati, Ohio) *Metallurgical Transactions*, vol. 1, no. 1 Jan. 1970 p 324-325 9 refs
(Contract AT(40-1)-2847)

A sample of AISI 304 stainless steel was used in low-cycle fatigue tests to determine if the introduction of hold periods at peak strain leads to a reduction in the cyclic fatigue life. Three types of strain wave forms were evaluated. Tests involving hold periods in the compression cycle only and tests involving hold periods in both tension and compression gave similar reductions in the cyclic fatigue life. Hold periods in only the tension portion of the cycle were found to be extremely detrimental and led to serious reductions in the cyclic fatigue life. The logarithmic plot of time to fracture vs. cycle time yields a distinct linear relationship for a given strain rate; it is then demonstrated that this correlation can be used to estimate fatigue behavior at other strain rates. From the graph of time to fracture vs. cycle time, it is also noted that the use of hold periods increases the actual time required to produce a fracture. P.R.F.

Review: Low-cycle fatigue at high temperatures is an important consideration in jet engines and the ability to predict material behavior under those conditions is an important part of a design effort. This paper extends the knowledge about holding periods, that is, periods during which the strain is held at maximum or minimum point. The scatter appears to be rather small, as is typical of low-cycle fatigue. Apparently, the damage induced by the holding periods is not represented as being analogous to creep or creep rupture, nor is any mention made of damage incurred at levels other than the maximum or minimum points on the cyclic curve. The article is both for theorists and designers since some design methods are implied by the curves and data.

R70-15325 ASQC 844; 782

HOSTILE ENVIRONMENTS VS. SNAP-ACTING SWITCHES

John P. Lockwood (Micro Switch, Freeport, Ill.) *Machine Design*, vol. 42, no. 3, Feb. 5, 1970 p 128-133

The effects of hostile environments on snap-acting switches are assessed. It is shown how such variables as high and low temperatures, thermal shock, and pressure differences can decrease the performance reliability of a switch. To avoid damage from moisture, contamination, and ice, guidelines are offered which aid in selecting either a sealed or an unsealed switch, in choosing the materials used in the construction of switches, in picking the proper coating for the switch, and in selecting the most suitable mechanical construction. The design of an explosionproof switch is also considered with the suggestion that it is best to test such a switch under the conditions expected in end use. P.R.F.

Review: This article contains qualitative design guides for engineers. It is not intended to replace detailed manufacturer's specifications, but rather to give the designer an insight into the kinds of things that can go wrong with switches and what can cause them, thus enabling the user to avoid problems. The explanations are somewhat long for a checklist but the article could certainly be saved for that purpose. (It might have helped if the author, in his introduction, had made a distinction between mechanical and contact life of switches.) A related article by this author (in the same journal) is "A snap-course in applying snap-acting switches," *Machine Design*, 2 Oct 69, pp. 122-127. This kind of article is a great help to design and reliability engineers since it often covers very practical subjects that are treated only slightly in schools and textbooks and about which the engineer must know something to do his job well. Not only does this kind of article provide him with a good background for making decisions, but it also gives him the vocabulary and concepts necessary so that he can discuss his problem intelligently with experts. Reliability is not mentioned explicitly, but it is implicit throughout the discussion.

R70-15326 ASQC 844; 773

ROLLING CONTACT FATIGUE LIFE EVALUATIONS OF BEARING MATERIALS

P. L. Colcord and J. R. Kildsig (General Motors Corp., Allison Div., Indianapolis, Ind.). *(American Society for Metals, Metals Engineering Congress, Philadelphia, Oct. 13–16, 1969.) Metals Engineering Quarterly*, vol. 10, no. 1 Feb. 1970 p 40-44 4 refs
(A70-22555)

Development of a three ball-cone test equipment for evaluating the bearing materials and bearing process. The test specimen is approximately 1 in. long with a cone ground on one end which has a 109 deg angle. The cone is rotated against three balls in a cup. The collet containing the cone specimen is rotated at 10,770 rpm, which is compatible with many operational applications in turbine engines, and enables testing to be completed in a reasonable period of time. IAA

Review: This article, as well as others, emphasizes the point that in the past, turbines have been limited by other conditions than their bearings, and therefore a tremendous amount of research and development went into those other factors in order to improve turbine engine performance. Apparently, those things are catching up because now attention is also being given to the bearings. This paper describes a tester for bearing materials. The description of the machine is not entirely clear; for example, no mention is made of the materials of the balls or raceway. Machine-to-machine variations are not discussed, although apparently this facility had at least three of the machines. No mention is made of scatter in the fatigue data; presumably the curves are median curves. The results on the materials are quite interesting and worthwhile. The graph (Figure 3) shows the characteristics which are the bane of those who do accelerated testing, namely, the curves seem to cross, so that one material is better at high loads and the other material may be better at low loads. Also, one of the materials does not have the S-N curve shape ordinarily ascribed to such curves. This paper is directed toward those doing research in bearing fatigue rather than to designers or reliability engineers.

R70-15327 ASQC 844
EVALUATION OF PREMIUM STRENGTH STRESS-COR-ROSION RESISTANT 7000-SERIES ALUMINUM ALLOY DIE FORGINGS
K. O. Mc Dowell (Boeing Co., Wichita Div., Wichita, Kan.) P. L. Hinkeldey, and H. W. Schimmelbusch (Boeing Co., Commercial Aircraft Div., Seattle, Wash.) *Metals Engineering Quarterly*, vol. 10, no. 1 Feb. 1970 p 45-50
(A70-22556)

Evaluation of the tensile, stress-corrosion resistance, fatigue, and fracture-toughness properties of an improved alloy 7175. Die forgings in both the stress-corrosion resistant, high strength temper and very high-strength temper were obtained. Two types of stress-corrosion tests were conducted. In addition, smooth and notched axial fatigue tests were conducted on both tempers. It is concluded that, the 7175 alloy subjected to a stress-corrosion resistant and high strength temper is very promising and the results obtained can be regarded as a breakthrough in its material technology. IAA

Review: The finding of "better" aluminum alloys is very important for airplane manufacturers. There are many criteria for "better" and the alloys covered in this paper are better in that they have (1) higher ultimate tensile strength, (2) higher yield strength, (3) adequate stress-corrosion resistance, and (4) adequate fatigue resistance; there was no comparison of elongation. There also was no conventional statistical analysis of the data. One of the very valuable things about a statistical analysis is that it tells more exactly what you do not know from the data; for example, the authors point out that there is a distinct difference in strength between samples from the two different forgings although they are nominally from the same material. To do a comprehensive analysis on this kind of material, then, one would need to run a statistically designed experiment which would include proper sampling techniques among the kinds of forgings. The fatigue curves are another example in which a statistical treatment of the data (such as suggested by ASTM Committee E-9) would be more helpful than merely a scatter band.

R70-15328 ASQC 844; 775
WHAT AUTOMATION CAN DO IN NONDESTRUCTIVE TESTING
Robert G. Strother (Magnaflux Corp., Chicago, Ill.) *Metal Progress*, vol. 97, no. 2 Feb. 1970 p 87-89

Two major trends in nondestructive testing are described: preprocess testing, finding defects early in the production cycle before dollars are spent in processing; and in-line testing, using data generated in continuous checks on part quality to take corrective action. Specific examples of automatic and semiautomatic inspection systems include ultrasonic and fluorescent magnetic particle methods, black light inspection, and eddy current testers. P.R.F.

Review: Nondestructive evaluation (NDE) is one of the important techniques for improving the reliability and quality of products. This article, naturally enough, deals largely with the NDE systems sold by the author's company and gives several examples of the use of those NDE methods which have been automated. The contents of the article are not startling for anyone who has been even modestly keeping up with the literature. Perhaps the purpose it best serves is to remind managers and others, who are responsible for quality and reliability, that it might pay them to look over their manufacturing processes to see if they can improve the effectiveness of both processes by introducing 100% automatic (or semi-automatic) NDE at some stages. For those who are already familiar with automation of NDE, there is no point in reading the paper.

85 DEMONSTRATION/MEASUREMENT

No abstracts in this issue.

86 FIELD/CONSUMER ACTIVITY

No abstracts in this issue.

87 MAINTAINABILITY

R70-15286 ASQC 872
EXCESS TIME: A MEASURE OF SYSTEM REPAIRABILITY
Eginhard J. Muth (Florida University, Dept. of Industrial and Systems Engineering, Gainesville) IEEE *Transactions on Reliability*, vol. R-19, no. 1 Feb. 1970 p 16-19 6 refs

Downtime and excess time are defined as measures of the accumulated time during which a system is inoperative. Excess time differs from downtime in that its parameter t counts only productive

units of time; therefore, B(t) is the excess of unproductive time over productive time. The probability law of excess time is postulated, and the conditional probability density functions of normalized excess time are graphed. Equations are derived to establish suitable distributional expressions as approximations to the actual distribution of excess time. M.G.J.

Review: This paper summarizes a portion of the author's Ph.D. dissertation and introduces a new random variable called *excess time*. This is a somewhat different measure of downtime than the usual one, and the author explores its statistical and mathematical ramifications. Reliability engineers would do well to be familiar with the concept in order to find out where in their work it might have application. The paper is quite mathematical, and those without a fairly solid background in mathematics and statistics will find it difficult reading. It is not necessary, of course, that they understand all the mathematics as long as they understand the concept of *excess time*. They can always get a statistician/mathematician to assist them in its implementation.

R70-15296 ASQC 872; 821
Wisconsin Univ., Madison.
OPTIMAL SPARES FOR STOCHASTICALLY FAILING EQUIPMENT
Charles H. Falkner Repr. from Naval Research Logistics Quarterly, v. 16, n. 3, Sep. 1969 p 287-295 refs
(AD-698959) Avail: CFSTI

A mathematical model is formulated for determining the number of spare components to purchase when components stochastically fail according to a known life distribution function and there is a cost incurred when a component is replaced. Bounds are determined for the optimal inventory which indicate that the inclusion of the replacement cost lowers the optimal inventory. Since these bounds are no easier to calculate than the optimal spares level, the theory is specialized to components with exponentially distributed time to failure. Procedures are given for calculating the optimal spares level, and numerical examples are provided. Author (USGRDR)

Review: The reliability of equipment is influenced greatly by its maintenance policies. The more exact the analysis of a maintenance policy can be, the better the reliability can be determined. This analysis, as stated by the author, is suitable only for exponentially failing equipment (constant hazard rate) since otherwise the analysis is too complicated. The repair time is not considered at all; more specifically, it is not considered to be a function of anything to do with the spares. This is a mathematical paper, and as such, will be much less accessible to design engineers than it will be to theoreticians. The author places his analysis in perspective with similar analyses very well and shows wherein he has made an improvement. No distinction is made in the paper between failure (hazard) rate and replacement rate. Perhaps it is not necessary in developing this theory; but it is very necessary in implementing it with numbers, since those two rates are known to be quite different.

R70-15300 ASQC 872; 821
Radio Corp. of America, Camden, N. J.
VALIDATION OF DISCARD-AT-FAILURE MAINTENANCE MATHEMATICAL MODEL Final Report 20 Feb. 1964 – 15 Jun. 1965
R. E. Purvis and R. L. Mc Laughlin Feb. 1966 196 p refs
(AF 30(602)-3336)
(N70-74821; RADC-TR-65-214)

A validation program is presented for a mathematical model directed to the establishment of economic decision criteria for determining the optimum discard-at-failure, or repair-at-failure, maintenance policy. Design guidelines are provided in the form of design/support alternatives available to the designer. Author

Review: This is a good report. The topic itself is important and is increasingly coming under intense scrutiny. Even though the report is several years old (the distribution limitation on this report has only recently been removed), the philosophy behind the procedure still applies. Before using the technique, one should be sure to read the sections on possible errors in the model and the discussion is excellent, not only for the particular situation in the report, but also as a general engineering approach. Reliability and design engineers should be acquainted with this material.

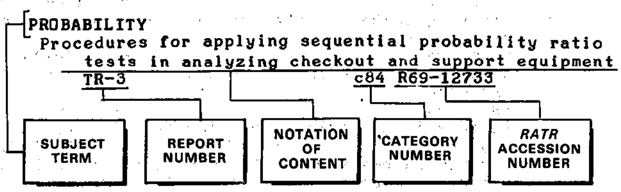
88 AVAILABILITY

No abstracts in this issue.

SUBJECT INDEX

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS VOLUME 10 NUMBER 10

Typical Subject Index Listing



The Notation of Content, rather than the title, is used to provide a more exact description of the subject matter. The category number and *RATR* accession number are used to locate the abstract-review appearing in the abstract section of *RATR*.

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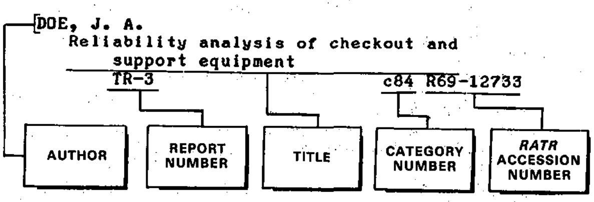
PERSONAL AUTHOR INDEX

Typical Personal Author Index Listing



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REPORT AND CODE INDEX

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS VOLUME 10 NUMBER 10

List of Report Numbers

This may be used to identify the *RATR* accession number of reports covered in this journal. To the right of each report number is the *RATR* accession number preceded by the category number for locating the abstract-review in the abstract section of *RATR*. For purposes of this index, AD, N, and A numbers (accession numbers from *TAB, STAR,* and *IAA,* respectively) and ASQC code numbers are treated as "report" numbers. Thus, the section of this index listing ASQC codes may be used to identify the *RATR* accession number of the coded abstract-reviews appearing in *RATR*.

ACCESSION NUMBER INDEX

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS VOLUME 10 NUMBER 10

List of *RATR* Accession Numbers

This list of *RATR* accession numbers may be used to identify the category in which a numbered abstract-review appears in the abstract section of this journal. Accession numbers are arranged in ascending order. Preceding each accession number is the category number for locating the abstract-review in the abstract section of *RATR*.

NASA-Langley, 1970

SPECIAL NOTICE INSIDE

Reliability Abstracts and Technical Reviews

NOVEMBER 1970

Volume 10
Number 11

R70-15329—R70-15378

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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SPECIAL NOTICE

Budget and personnel stringencies make it necessary for NASA to discontinue *Reliability Abstracts and Technical Reviews (RATR)* at the end of this calendar year.

Publication of *RATR* will cease with issuance of the Annual Index for January–December 1970.

There are no plans to institute any similar-type publication.

Reliability and Quality Assurance Office
National Aeronautics and Space Administration

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The second section of *RATR* contains four indexes: The Subject Index is to assist in scanning or searching the literature on specific topics. The Personal Author Index identifies the publications of specific authors. The Report and Code Index is a listing of the report numbers of items abstracted and reviewed in the journal; this index also includes a listing of the ASQC codes for identifying the *RATR* accession numbers of the items to which the codes have been assigned. The Accession Number Index identifies the categories in which the abstract-reviews appear in the journal. Cumulative indexes are published annually.

EXAMPLES OF CITATIONS IN *RATR*

		ASQC CODES
RATR ACCESSION NUMBER	R70-12733 ASQC 844; 413	CORPORATE SOURCE
TITLE	General Equipment Company, Banville, Calif.	
	RELIABILITY ANALYSIS OF CHECKOUT AND SUPPORT EQUIPMENT	PUBLICATION DATE
AUTHOR	John A. Doe 23 Sep. 1969 27 p refs	
CONTRACT OR GRANT	(Contract NAS15-13411)	*TAB* AND *STAR* ACCESSION NUMBERS
	(AD-629305; N69-15098; TR-3) Avail: CFSTI	
REPORT NUMBER		SALES AGENCY AND PRICE

RATR ACCESSION NUMBER	R70-12739 ASQC 814	ASQC CODE
TITLE	**SEMICONDUCTOR RELIABILITY**	
	Joseph A. Smith (Eastern University, Arlington, Penn.)	AUTHOR AND AFFILIATION
	Electric Journal, vol. 8, Apr. 1969, p 478–492.	
JOURNAL REFERENCE	(A69-12569)	*IAA* ACCESSION NUMBER

RATR ACCESSION NUMBER	R70-12765 ASQC 773; 221; 823	ASQC CODES
	TESTS OF SYSTEMS WITH SOME DEPENDENT FAILURES	
	Joseph A. Smith (Eastern University, Arlington, Penn.) and	
TITLE	B. James White (General Equipment Company, Banville, Calif.)	AUTHORS AND AFFILIATIONS
	Association of Reliability Engineering, Failure Rate Conference,	
CONFERENCE OR SYMPOSIUM REFERENCE	*Olney, Tex., Mar. 13–17, 1969, 8 p.* Available from Assoc. of	AVAILABILITY AND PRICE
	Reliability Eng., New York: $1.00	
IAA ACCESSION NUMBER	(A69-12407)	

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81 MANAGEMENT OF RELIABILITY FUNCTION

R70-15343 ASQC 814; 815; 870

Air Force Logistics Command, Kelly AFB, Tex. Directorate of Aerospace Fuels.

LIFE CYCLE PROCUREMENT OF LOX VALVES. A CASE STUDY WITH CONCEPTS, DEVELOPMENT PHASES AND ACTUAL SOLICITATION Summary Report

Herbert N. Soule Oct. 1969 16 p refs

(N70-21454; AD-697396; OQF-10) Avail: CFSTI

The document contains the summary of a real life cycle procurement of a non-reparable liquid oxygen female filler valve. Author (TAB)

Review: The interesting feature of this report is that it deals with an actual procurement situation where reliability, maintainability, and life cycle cost are brought together. The author of the report (who most likely is not a reliability engineer) is apparently convinced that by spending a little more initially for valves with higher reliability, substantial savings in support costs will be achieved. This sort of situation is the ultimate payoff for the earlier efforts of reliability and related workers. The present report is about the procurement plan and its development. The author is encouraged to follow up this report with later publication of the reliability test data and related results of the LOX valves procurement.

R70-15359 ASQC 810

THE CHANGING PHILOSOPHY OF RELIABILITY

K. J. Young (Gloucester House, B. H. Crowthorne, Berks, RG11 7EG.) *Microelectronics and Reliability*, vol. 9, no. 2 Mar. 1970 p 133-135 2 refs

Chief factors in the improvement of consumer and industrial equipment are analyzed. The trend toward miniaturization is seen as improving reliability in such devices as transistors and silicon rectifiers; it is pointed out, however, that other devices may be less reliable than their bulky predecessors because miniaturization places more acute demands on tolerances, clearances, and control of heat dissipation, and may render maintenance more difficult. The increasing emphasis on minimizing cost and standardization of some equipment is assessed on the basis of their effect on factors of safety. Suggestions are made to improve the design of control knobs, the markings of very small components, the usefulness maintenance manuals, and the service life and safety of fuses. Cleaners and the cleaning of parts are discussed. Finally, guidelines are given for choosing batteries according to their intended use in order to improve reliability and minimize cost. P.R.F.

Review: This is an essay on some topics that have apparently caught the author's attention recently. It deals largely with consumer and industrial equipment and is not concerned with quantitative measures of probability of failure. The points made are those with which most users would agree. Obviously, manufacturers do not agree wholeheartedly, perhaps because they think they have more important things about which to be concerned. This is not an article one needs to search out to read, but it is interesting and short if one should chance upon it.

R70-15361 ASQC 815; 851

AN INTERPRETATION OF CERTAIN A.G.R.E.E. PRINCIPLES

Z. S. Siemaszko (Twyford Ave., London, W.3) *Microelectronics and Reliability*, vol. 9, no. 2 Mar. 1970 p 167-176 7 refs

Important features of the Advisory Group on Reliability of Electronic Equipment (AGREE) testing methods are discussed. The relation between the probability of acceptance and the lot percentage defective is translated into the relation between the probability of acceptance and the MTBF (mean-time-between-failures) of a batch subjected to test. It is found that the distribution obtained after a short operating time of individual equipments does not represent a true picture and the distribution of reliability level of individual equipments is assessed more accurately only over a long operating time, i.e. when the number of failures of individual equipments is appreciable. In order to achieve a financially acceptable condition, it is stated that the equipment must have a higher reliability level than that specified in the contract. It is also explained how the censorship procedure is of little assistance to the producer. Author

Review: This paper attempts to interpret some of the AGREE principles. Unfortunately, the conceptual model upon which some of the tests in the AGREE report are based is not clearly spelled out

in that report; nor is it spelled out clearly in this interpretation. Thus, the paper is confusing and obfuscated. Furthermore, it is not explained why anyone should be wanting to interpret the AGREE report (1957) after thirteen years. Some of the principles in it have been embodied in specifications and standards written since then, and it would be more important to analyze those than the original AGREE report. Since the necessary statistical sophistication is very small for analyzing the apparent models in AGREE, there is no reason nowadays for not being very clear about these conceptual models. There are several sections to the AGREE report, not all of which are internally consistent; so it helps to refer to specific sections of the report rather than to just the entire report (apparently it is the report of Task Group 3 which is being referenced). The biggest difficulty lies in deciding whether the conceptual model requires all of the equipments to have the same exponential parameter or not. If they are all the same, then the observed parameters for each equipment will have a distribution related to that of chi-square. If they are not presumed to be the same, then one needs to make some kind of assumption about how they are distributed before going ahead with the statistical analysis. One interpretation of the AGREE section is that all but a few of the equipments have the same parameter, and those few will have a parameter substantially lower than the others. These are referred to as the defective items and are the ones which are potentially censorable from the data. The author makes the assumption, apparently based on some experimental data, that the observed MTBF will be distributed according to a Poisson distribution (this is not clear since the Poisson distribution is for a discrete variable while the MTBF is ordinarily considered to be a continuous variable). This situation, involving the assumption about the distribution of the MTBF, is also a major cause of the difficulty in interpreting the different OC curves for what are presumably the same sequential tests. If the presumption is that they all have the same exponential parameter, then which or how many samples one picks makes no difference. If that is not the presumption, then it is encumbent upon the analyst to make his own presumption explicit. In summary, this report does little if anything to either interpret or clarify the Task Group 3 section of the AGREE report. Such clarification and interpretation can only be done by postulating very explicit conceptual models and then analyzing them.

82 MATHEMATICAL THEORY OF RELIABILITY

R70-15329 ASQC 824

APPROXIMATIONS TO SYSTEM RELIABILITY USING A MODULAR DECOMPOSITION

Lawrence D. Bodin (California University, Operations Research Center, Berkeley) *Technometrics*, vol. 12, no. 2 May 1970 p 335-344 5 refs

(Contracts Nonr-3656(18); DA-31-124-ARO-331; Grant GP-7417)

To compute system reliability, a new lower bound procedure based on the modular decomposition of a coherent structure is proposed. It is shown that this procedure provides a sharper lower bound estimate of the system reliability of a coherent structure than other methods and is computationally more efficient. Author

Review: This is a slightly revised version of the report covered by R68-14174.

R70-15330 ASQC 824

ESTIMATORS AND EXACT CONFIDENCE BOUNDS FOR WEIBULL PARAMETERS BASED ON A FEW ORDERED OBSERVATIONS

Nancy R. Mann (Rocket Dyne, Canoga Park, Calif.) *Technometrics*, vol. 12, no. 2 May 1970 p 345-361 20 refs

(Contract AF33(615)-2818)

A two-parameter Weibull model is assumed, and the problem of obtaining exact confidence bounds for the shape parameter and for reliable life is considered in detail. Analytically derived bounds for both of these parameters based on only a few ordered observations are shown to be highly efficient with respect to those derivable by Monte Carlo procedures using all the ordered observations. Tables are given for obtaining bounds on and estimates for the shape parameter and reliable life for two values of a specified survival proportion. Author

Review: In this paper, the author makes a further contribution to the mathematical methodology available for reliability estimation based on the Weibull distribution. For earlier papers by the author, see R68-13758, R68-14099, R69-14371, R69-14609, and R69-14610. The material in this paper is clearly presented, well documented, and the mathematical work is competent. The parameters referred to in the title are the shape parameter and reliable life. The advantage of this method over the available non-parametric methods of obtaining confidence bounds on reliability parameters is brought out. The Weibull distribution is often used in reliability estimation (when it is desired to model a situation in which the hazard rate is non-constant). Thus, the results in this paper are of practical value. However, some sophistication in statistical methodology will be necessary in order to apply them properly.

R70-15331 ASQC 824

MAXIMUM LIKELIHOOD ESTIMATION, EXACT CONFIDENCE INTERVALS FOR RELIABILITY, AND TOLERANCE LIMITS IN THE WEIBULL DISTRIBUTION

Darrel R. Thoman (William Jewel College, Mo.), Lee J. Bain (Missouri University, Rolla), and Charles E. Antle (Pennsylvania State University, University Park) *Technometrics*, vol. 12, no. 2 May 1970 p 363-371 5 refs

(Contract F 33615-70-C-10108)

The results of a study of the maximum likelihood estimator, $\hat{R}(t)$, of the reliability, $R(t)$, are presented. The two-parameter Weibull distribution is assumed. Tables of lower confidence limits for the reliability are provided and the large sample normal approximation for $\hat{R}(t)$ is investigated. Tolerance limits based on the maximum likelihood estimators of the Weibull parameters are developed. It is found that the tables needed for obtaining confidence intervals for $R(t)$ also enable one to obtain lower tolerance intervals. An example is given to help clarify the procedure. Author

Review: This paper represents a continuation of work by the authors on maximum likelihood estimation in relation to the Weibull distribution (see the paper covered by R70-14854). The attention in this paper is on the reliability function when the two-parameter Weibull distribution is assumed. Tables for obtaining lower confidence limits for the reliability as well as lower tolerance intervals are given. The material is clearly presented, and a number of related references are cited. The mathematics was not checked in detail, but a spotcheck contribution to the mathematical methodology pertinent to reliability estimation, since the Weibull distribution is

of quite common occurrence in reliability data. The paper will be of interest to those concerned with the analysis of Weibull data as well as to the reliability theorist. An example helps clarify the procedure.

R70-15332 ASQC 824; 424

ESTIMATION OF PARAMETERS IN COMPOUND WEIBULL DISTRIBUTIONS

Lee W. Falls (NASA. Marshall Space Flight Center, Huntsville, Ala.) *Technometrics*, vol. 12, no. 2 May 1970 p 399-407 9 refs

Presented is the method of sample moments for estimation of the parameters of a compound Weibull distribution with two shape parameters, two scale parameters and a proportionality factor. It is noted that the occurrence of compound distributions is quite common in the analysis of atmospheric data and, consequently, is of interest to aerospace scientists. Author

Review: This is a condensed and revised version of the report covered by R68-13699.

R70-15333 ASQC 824; 822

PLANNING CENSORED LIFE TESTS FOR ESTIMATION OF THE HAZARD RATE OF A WEIBULL DISTRIBUTION WITH PRESCRIBED PRECISION

L. Danziger (IBM Corp., New York) *Technometrics*, vol. 12, no. 2 May 1970 p 408-412 2 refs

Criteria are described for designing a life test to estimate the Weibull hazard rate with prescribed precision based on the first r out of n order statistics $t_1 < t_2 \ldots < t_r$ and known shape parameter m. Tables for the required number of failures and graphs for choosing a desirable sample size are provided. Author

Review: This is a brief mathematical paper which accomplishes the objectives indicated by the title. Tables are provided for the number of failures required to estimate an upper bound on hazard rate and a lower bound on hazard rate, the shape parameter being assumed known. The effect of increasing the sample size in order to save test time is worked out and depicted graphically. Thus, the paper presents very useful results for those who are designing life tests aimed at estimating the Weibull hazard rate. The requirement that the shape parameter be known may by unduly restrictive in many reliability applications.

R70-15334 ASQC 824

ON PROPORTIONAL HAZARD FUNCTIONS

Arthur Nadas (Polytechnic Institute of Brooklyn, N. Y. and IBM Corp., N. Y.) *Technometrics*, vol. 12, no. 2 p 413-416 1 ref

The proposition is offered that the minimum of independent random variables X and Y is independent of the event $X < Y$ if and only if the hazard functions of X and Y are proportional. Although only the case of two random variables is considered, it is stated that the result clearly extends to any number of independent random variables. Proofs of the proposition are presented for both the absolutely continuous case and the purely discrete case. P.R.F.

Review: In this brief mathematical note the author proves that the minimum of independent random variables X and Y is independent of the event X < Y if and only if the hazard functions of X and Y are proportional. The result is applicable to more than two random variables. It will be of interest to statisticians concerned with designing life tests—in fact the author discovered it while dealing with a problem in life testing.

R70-15338 ASQC 824; 810

Army Foreign Science and Technology Center, Washington, D.C.

PROBLEMS IN THEORY OF TESTING PRODUCTS FOR QUALITY AND RELIABILITY

B. V. Gnedenko 1968 10 p refs Transl. into ENGLISH from Standarty i Kachestvo (USSR), v. 31, no. 5, 1968 p 77-79 (AD-844347; FSTC-HT-23-227-68) Avail: CFSTI

Methods of quality control are discussed and reference materials are cited for the purpose of further research on the subject of theory, methods, and other aspects of quality control. Reliability is regarded as a fundamental characteristic of quality. The theory of tests is considered in the light of mathematical statistics. The need to reduce testing time in quality control is emphasized. Author (USGRDR)

Review: This paper treats the subject of its title in a general fashion. The author is well known for his work in probability and statistics, and in particular, as applied to reliability. The points he makes are good ones. The early part of the paper is general and suitable for managers to introduce them to the need for mathematical models and the use of statistics. The second part uses some mathematical/statistical notation in several examples to illustrate the earlier points. The paper is reasonably well written (the translation, although a rough one, is relatively easy to read). While one need not go out of his way to find a copy since there is similar material in the English-language literature, if he has access to a copy, it is worth the short time it takes to scan it.

R70-15363 ASQC 824; 433

Atomics International, Canoga Park, Calif. Liquid Metal Engineering Center.

BAYESIAN STATISTICAL MODEL THEORY FOR MECHANICAL SYSTEMS

J. P. Walter 31 Aug. 1969 94 p refs
(Contract AT(04-3)-700)
(N70-20430; LMEC-69-8)
Avail: CFSTI

The experiment sequencing problem is restated as an optimization problem, the object of which is to maximize information gained from experimentation; numerous candidates for an information gain function are introduced. Sequential Bayes estimation procedures are discussed for both parametric and empirical applications, where the methods of Hammond, Richardson, and Rutherford are presented. Examples include: (1) an instance of sequential Bayes point estimation on the basis of computer simulated Gaussian data, and (2) implementation of a technique for actual metallurgical experimental data, the errors of which are postulated to be Weibull-distributed. Author (NSA)

Review: This paper is on an important topic, but one which has yet to be applied extensively to reliability theory. The title of the paper is somewhat misleading since it is not at all limited to mechanical systems, rather it discusses methods for experimental design and measures of information gained from experiments. Much of the discussion is rather general (even though some formulas are given), in that only the broad outlines are covered; the details of application are left to the reader. This paper will be an important

resource document for engineers who plan to do work in the field since it gives quick and ready reference to much of the earlier work. In the discussion of Shannon entropy (continuous variable case), no mention is made of the measure function which is sometimes introduced in order to make the information independent of transformations of variables. There is a particularly helpful table giving natural conjugate densities for the Bayesian approach.

R70-15365 ASQC 822
Georgia Univ., Athens.
A GENERALIZATION OF THE WEIBULL DISTRIBUTION
A. Clifford Cohen Huntsville, Ala. NASA. Marshall Space Flight Center 31 Jul. 1969 23 p refs Revised
(Contract NAS8-11175)
(N69-35624; NASA-CR-61293; TR-31-Rev) Avail: CFSTI

The two-parameter Weibull distribution with origin at zero and the three-parameter version of this distribution with origin at γ are widely employed as statistical models in connection with life testing. In this paper a four-parameter generalization of this distribution is introduced in order to provide a more versatile model for use in life studies and in related investigations. The problem of parameter estimation is considered and three separate sets of estimators are presented. These are (1) moment estimators, (2) maximum likelihood estimators, and (3) alternate estimators based on the first three moments and the first order statistic. Author

Review: This is a mathematical/statistical paper whose purpose is to introduce another distribution; in particular one which may be useful in life-testing situations. The distribution itself is a cross between the gamma and Weibull distributions and can be viewed as a generalization of either. Two methods of estimating the parameters are derived (moment and maximum likelihood). *There is, unfortunately, no discussion of the uncertainties involved* in such parameter estimates. Since the analysis of uncertainties is one of the main functions of statistics, it remains to be done before this function can be useful in life-testing analysis. Engineers, especially, are much too prone to take estimates at their face value, and they need the constant reminder of uncertainty that statistics can provide. It is true, as the author points out, that this distribution is more flexible than a three-parameter distribution. Whether or not this is desirable is something else again. The difficulty in choosing a distribution for life testing in aerospace reliability is ordinarily not that one cannot find a distribution that will fit but that he can find too many distributions which will fit; that is, there are so few data that the ability to distinguish between their fits is very poor. Before applying this distribution extensively, it would help to know what physical models are implied by this distribution.

R70-15370 ASQC 824; 433
Purdue Univ., Lafayette, Ind. School of Electrical Engineering.
MUTUAL UNCERTAINTY AND PRIOR PROBABILITIES
Rangasami L. Kashyap Jul. 1969 50 p refs
(Grants AF-AFOSR-1776-69; NSF-GK-1970)
(N70-16326; AD-695819; TR-EE69-22; AFOSR-69-2697TR) Avail: CFSTI

The paper gives a general method of determining the prior probability function of a variable Lambda using only the prior *knowledge which comprises the measurement scheme relating the* observables X(1),X(2), . . . to Lambda, the range of Lambda and the additional knowledge such as the bounds on the expected value of Lambda. The essential idea is that one should not be able to draw any conclusions on the observable random vectors X(1),X(2), *. . . which are not explicitly permitted by the prior knowledge.* This leads us to the principle of Maximum Mutual Uncertainty for the determination of the prior probability function is all the cases. In particular, one can derive a rather simple formula for the prior density of a parameter. It is shown that the principle of Maximum Entropy developed by Jaynes for the determination of the prior density of the observable random variable is a special case of the principle of Maximum Mutual Uncertainty. A number of examples have been given to demonstrate the power of the method. Author (TAB)

Review: This interesting paper attempts to make the concept of statistical ignorance more precise. It extends the work of E. T. Jaynes in this respect and derives results some of which are algebraically equivalent to those which have been obtained in the past but to which the author gives either a different interpretation or more insight. The work is accessible only to those with a considerable background in theoretical statistics. The general topic should be pursued because it is so important to many applications of statistics. The author is to be commended for attempting this unifying view. *This whole subject is important in the theory of reliability since* there is so much we do not know, especially about the forms of distributions and the values of their parameters, and since much of the information which engineers have on this topic is very difficult to quantify. This paper undoubtedly is not the last word in this area since the topic is controversial and has been for many years. It is not entirely clear that the author has solved the problem where the parameter has a continuous distribution. He does not mention the measure function which Jaynes introduced and which accounts for the transformation of variables. Very briefly, the difficulty with the continuous variable is that we cannot associate a probability with a point value of that argument but only with a range of values. The way in which this range varies with the variable affects very much the answer one gets (assuming that he has not introduced the measure function). This particular difficulty also intrudes wherever one tries to transform the continuous variable into a discrete one (the reason for the transformation is that the discrete case is readily solved). In a sense, of course, all papers such as this try to make worthwhile *definitions* of ignorance since one cannot describe it without first defining it, but complete ignorance is difficult to define. There are those who believe that while the effort above is very interesting from an academic point of view, it is much more worthwhile to figure out how to quantify our knowledge and describe it rather than to define a very illusive concept of ignorance. The author mentions that Jaynes' principle of maximum entropy has been quite successful in physics. Its success is rather limited since in addition to the principle of maximum entropy, one has to be a master of coincidence in order to choose the constraints so that he gets the right answer.

R70-15373 ASQC 824
Florida Univ., Gainesville. Dept. of Industrial and Systems Engineering.
A BIVARIATE EXPONENTIAL DENSITY AND A TEST THAT TWO IDENTICAL COMPONENTS IN PARALLEL BEHAVE DIFFERENTLY
J. G. Saw Aug. 1969 26 p ref
(Contract DAHC04-68-C-0002)
(N70-21256; AD-696485; Themis-UF-TR-22) Avail: CFSTI

In order to increase the reliability of a system, two (or more) components may be joined in parallel. The system will function normally until both (or all) components have failed. Frequently it may be assumed that, functioning alone, each component has an

exponentially distributed life length although it may not necessarily be true that the joint density on the life length of the two (or more) components acting in parallel is the product of the univariate marginal densities. A bivariate exponential density is derived and the uniformly most powerful test of the hypothesis of independence of life length of two components operating in parallel is obtained. Author (TAB)

While the emphasis for this paper is on a reliability problem and the results are applicable to the reliability field, the paper is a theoretical one and will be of benefit only to those who are able to apply such theory on their own. (Not all the mathematics was checked, but it appears to be competent.) The work is in an area where little has been done. It is an important area, namely, that concerned with statistical independence of events and a redundant structure. Unfortunately, there are often too few data to make the power of the proposed test at all useful, but situations will arise where the tests can be useful, providing the statistician on the job knows they exist (and such of course in the purpose of the paper). It also helps if reliability engineers are at least aware of the possibility of running this kind of test, so that they can bring it to the attention of someone who can properly interpret and apply it.

R70-15376 ASQC 824
Stanford Univ., Calif. Dept. of Statistics.
SOME LOWER BOUNDS OF RELIABILITY
Tapas K. Sarkar 10 Aug. 1969 97 p refs
(Contract Nonr-225(53))
(N70-18781; AD-697292; TR-124) Avail: CFSTI

Consider a series system with n components. Let X_i be the time to failure of the (i)th component. Let R(t) be the reliability of the system at time t and R*(t) be the reliability when the components are independent. It is desired to find physically meaningful conditions such that R*(t) is a lower bound of R(t) for all t. Author (TAB)

Review: In this paper, the author is concerned with only one lower bound in reliability, namely, that calculated by assuming statistical independence. He is then concerned about trying to find some meaningful sufficient conditions for this theorem to hold. He considers both series systems and parallel systems and notes that the two are not completely analogous. This is a scholarly, theoretical treatment; the author takes as much pains to show what he cannot prove as what he can prove. Due to its theoretical format, the paper is accessible only to those with considerable background in theoretical statistics or mathematics and will provide impetus for further research. The paper, as it stands, is of no direct value to design and reliability engineers even though eventually this kind of work may lead to easier calculations.

R70-15378 ASQC 821
A DIFFUSION METHOD FOR RELIABILITY PREDICTION
G. S. Glinski, John B. De Mercado, and Philip M. Thompson (Ottawa University, Dept. of Electrical Engineering, Ontario, Canada) IEEE *Transactions on Reliability*, vol. R-18, no. 4 Nov. 1969 p 149-156 11 refs
(Grants A3379; A875)

Elements of the theory of diffusion processes are utilized to develop methods for predicting the reliability and the moments of the time to first failure of systems that have nonconstant failure rates and exhibit degradation failure. Specifically, systems characterizable by *k* independent parameters are considered, each of which independently exhibits degradation failure. The methods presented for obtaining a probabilistic description of such systems rest on the assumption that the time behavior of each of the system parameters can be characterized by a Brownian process (a special type of diffusion process). The methods then allow predictions of reliability and the moments of the time to first failure to be made from data taken early in life tests. In particular, the first moment is the mean time to first failure of the system. Author

Review: This paper treats the subject of reliability at a level which is rather sophisticated for reliability engineers, and thus will be of value largely to those doing research. Its purpose (to show that reliability prediction theory for degradation-prone systems can be expressed in the modern theory of continuous Markov processes) is laudable since new insights are badly needed. Two points which the reader should consider carefully are (1) the definition of reliability is not the conventional one, but has been modified to be tractable in the context of diffusion methods; (2) it is not entirely clear what the limitations are on assigning the parameters X^i to the system. For example, if the system is considered to be made up of several statistically independent subsystems which are logically in series, and if each subsystem has only one parameter to describe its performance, then there is some difficulty involved in interpreting the mean time to first failure for the parameters. This may be caused by "peculiarities" inherent in the behavior of a diffusing system which is quite different from the systems a reliability engineer usually treats.

83 DESIGN

R70-15335 ASQC 837; 844
FACTORS OF SAFETY UNDER CYCLIC THERMAL LOADING
S. V. Serensen and R. A. Dulnev *Russian Engineering Journal*, vol. 49, no. 4 1969 p 6-7 5 refs

A method of calculating the strength of components subjected to cyclic thermal loading is described, based on the resistance to long-term static failure. Author

Review: This theoretical paper deals with a combination of creep-rupture and thermal-fatigue. No experimental data are presented to substantiate the analytic method which is a type of linear interpolation according to a parameter which represents the relative amount of fatigue. Thus this paper will be of value to those doing research in thermal fatigue rather than to design engineers. In the absence of any other formulas in which one has more faith, a designer might, however, wish to try this method.

R70-15340 ASQC 833
PRECLUDE FAILURE: A PHILOSOPHY FOR MATERIALS SELECTION AND SIMULATED SERVICE TESTING
Thomas J. Dolan (Illinois University, Dept. of Theoretical and Applied Mechanics, Urbana) (*Society for Experimental Stress Analysis, Fall Meeting, Houston, Tex., Oct. 14-17, 1969.*) *Experimental Mechanics*, vol. 10, no. 1 Jan. 1970 p 1-14 33 refs
(A70-19235)

Discussion of the important role played by proper materials selection, design, analysis, fabrication and maintenance in the preclusion of failures. It is pointed out that a philosophy of design and prototype evaluation based on the prevention of failure is more

sound and workable than the stereotyped application of empiricisms, codes, specifications and factors of safety now commonly used. Reliance on design for static loadings and for factors of safety based on tensile strength as a criterion are frequently erroneous and dangerous. A variety of failures is discussed to emphasize the factors that must be considered in the selection of an optimum material and in prescribing an effective method of simulated-service testing. It is noted that considerable latitude in the use and misuse of equipment must be foreseen in order to predict possible modes of failure. A broad consideration of service environment is necessary for correcting faulty design and selecting proper materials which will withstand modifications due to processing, fabrication, maintenance or repair operations that lead to failure. IAA

Review: This is an excellent article. It is worth reading and studying by reliability and mechanical design engineers and by metallurgists involved in design. For some reason or other, the kind of information contained in this article must be repeated again and again. Failure, like so much else, is a multi-faceted thing. This article illustrates as graphically as possible (and the reproductions of the photographs are quite good) the many different kinds of strength a material must have and many of the different ways in which mechanical parts can fail. Emphasis is on the necessity of foreseeing (and designing for resistance to) *all* possible modes of failure; changes in material properties caused by processing or service environments must be anticipated. The author enjoys an excellent reputation in his field as illustrated by the fact that he was invited to present this lecture. This paper deserves wider circulation among the "nuts and bolts" engineers than it will probably receive. The reliability of every aerospace vehicle is vitally affected by the materials considerations explained here by the author. Reliability engineers (who often have come up through the route of electronics) need to be concerned especially that they educate themselves in the mechanical and metallurgical nature of failure. This article presumes some knowledge of the vocabulary in those two fields, but any reliability engineer who cannot intelligently read this paper ought to improve his vocabulary.

R70-15344 ASQC 830

Stanford Research Inst., Menlo Park, Calif.

TECHNIQUES FOR THE REALIZATION OF ULTRARELIABLE SPACEBORNE COMPUTERS Interim Scientific Report

J. Goldberg, H. S. Stone, A. Waksman Dec. 1968 186 p refs (Contract NAS-12-33; SRI Proj. 5580)

(N69-23811; N69-29962; NASA-CR-86141; NASA-CR-86156; ISR-4; IS R-2) Avail: CFSTI

The techniques developed are in support of computer structures in which reliability is achieved through autonomously controlled logical reconfiguration and fault masking. A multiprocessor model is described that is particularly appropriate to the attainment of ultrareliability. Local design techniques, which facilitate reconfiguration, are discussed for various computer functions. Design techniques are presented for economical, fault-tolerant, data commutation networks, including networks based upon crossbar-type switching arrays. Schemes are developed for accommodating switching failures and for embedding logic for the control of alternative switching setups within the network. Several schemes are developed that are appropriate for random and correlated fault types. Criteria for the selection of an instruction set for a spaceborne computer are considered. Merits are found for the use of stack-organized instructions, together with special registers for specifying the context of a process. Possible advantages of indirect addressing are also discussed. Author

Review: Every digital systems engineer concerned with reliable design should become familiar with these reports. The primary objective of this series of reports was to carry out research to advance the state-of-the-art in the design of ultrareliable spaceborne computers. Unfortunately, some of the reports in the series were not distributed by NASA and are not available from the originating agency (Stanford Research Institute). The techniques developed are to be used in support of computer structures in which reliability is achieved by controlled logic reconfiguration and fault masking. The reports are very comprehensive and tend to concentrate on presenting the information in a highly readable form without the formalism which might be cumbersome to a non-specialist in this field.

R70-15345 ASQC 830

Air Force Systems Command, Wright-Patterson AFB, Ohio. Foreign Technology Div.

PRINCIPLES OF AUTOMATIC DETECTION OF MALFUNCTIONS IN DIGITAL COMPUTERS

S. G. Denisov et al Feb. 1970 11 p refs Transl. into ENGLISH from the Russian

(N70-36226; AD-704001; FTD-HT-23-39-70) Avail: CFSTI

The digital computer is regarded as a Mealy automation whose output is determined by its input and its state at the preceding moment of time. All possible states operable and faulty are described by sets of subautomata where the first set represents operable states. K distinguishable automata are defined. In a complete fault detection system, any subautomaton can be identified with a class of indistinguishable among themselves faulty subautomata. In practice, the computer is subdivided into several units (storage, arithmetic unit, control unit, input-output), and each unit is checked separately. Program search for faults is based on a "step by step expanding regions" principle. The checking of each element of a digital computer is conducted in the same sequence in which the computer input is normally processed. Author

Review: The purpose of this edited translation of a Russian text is to describe a means of detecting errors in digital machines. The authors' approach is to properly choose the input sequences to differentiate between a fault-free machine and any faulty version of the same machine. This testing philosophy is well known; however, it is thought to be of practical value only for simple machines with a restricted class of failures. The authors point out some of the shortcomings of their method and suggest conditions under which the approach might be useful. (Only one minor translation error was noted. Some of the terminology in the paper is unconventional, e.g., "condition" is used rather than "state" when referring to the state of an automaton.) The paper is mainly of theoretical interest to those doing research in the field. The interested reader should also be aware of the material in Chapter 3 of [1].

Reference: [1] Chang, H. Y., E. G. Manning, and G. Metz, *Fault Diagnosis of Digital Systems*, Wiley-Interscience (1970).

R70-15347 ASQC 831; 844; 872

AN ALGORITHM TO COMPUTE A TEST TO DISTINGUISH BETWEEN TWO FAILURES IN A LOGIC CIRCUIT

J. Paul Roth (IBM, Thomas J. Watson Research Center, Yorktown Heights, N. Y.) IEEE *International Computer Group Conference, Washington, D. C., Jun. 16–18, 1970, Paper* 5 p 4 refs (RC 2716)

It is stated that the D-algorithm is used to detect a particular failure in logic circuits. A description is given of the distinguishing algorithm, and a proof is presented of its effectiveness. P.R.F.

Review: Fault diagnosis can play an important role in increasing system reliability and maintainability. This paper introduces a technique to distinguish among logical failures in a system. The author's competency is well established and his contributions are well known to the specialist in digital-systems fault-diagnosis. This paper is an extension of some of his earlier work and the reader must be familiar with the D-algorithm (to compute a test to detect a given failure in a logic circuit) which was employed in past publications. The novice may find that gaining an understanding of the author's previous publications is a difficult task; he will, therefore, appreciate the section in Chapter 3 of [1] which serves as an introduction to these papers. Both theoreticians and digital design engineers will find this paper of value.

Reference: [1] Chang, H. Y., E. G. Manning and G. Metz, *Fault Diagnosis of Digital Systems*, Wiley-Interscience (1970).

R70-15349 ASQC 830

SOME PROBLEMS IN DESIGNING OPTIMAL ELECTROMECHANICAL AUTOMATION DEVICES TAKING RELIABILITY INTO ACCOUNT

T. M. Vorobeva, K. A. Iyudu, and V. N. Kruglov (*Avtomatika i Telemekhanika, no. 10, Oct. 1969, p 132-136 In Russian.) Automation and Remote Control*, no. 10 Oct. 1969 p 1665-1669 2 refs

Avail: $15.00

The general content of basic problems in the design of optimal electromechanical automation devices is formulated, taking reliability into account. In optimizing automation elements it is proposed to start with the bogey function $\Pi = \Pi(xi)$ $(i = 1, 2, \ldots, n)$, evaluating device usefulness, i.e., the degree of device correspondence to the problem at hand. An example is given for the solution of the problem of minimizing the specific use cost of electromagnets. Author

Review: This paper uses a very straightforward approach of estimating the cost of ownership by including the usual factors of operating costs, the costs of failures and repairing thereof, etc. In an example, specific functional forms are assumed which are tractable enough so that conventional calculus can find the optimum operating point. This is a good example for those who have never seen it done. Those who are acquainted with this kind of thing will find nothing new in the paper. An important consideration not mentioned in the paper is that any such model is of necessity incomplete. Since the optimum point is one in which small variations of the parameters make little difference in the performance. The factors which have not been considered in the model may then be applied to determine where in this region one should operate. Very often, the region is extremely broad and factors of two in a parameter may cause operational performance degradation of only 10 or 20%. In one problem in the literature, which was analyzed in the paper covered by R70-15248, the minimum was so broad that as long as the pertinent parameter was large enough (and that was not difficult), other considerations not included in the analysis would completely overshadow the effect of a parameter being analyzed.

R70-15350 ASQC 833; 844

PLASTIC SEMICONDUCTOR DEVICES AND INTEGRATED CIRCUITS FOR MILITARY APPLICATIONS

Bernard Reich (Army Electronics Command, Electronics Components Lab., Fort Monmouth, N. J.) *Solid State Technology*, vol. 13, no. 1 Jan. 1970 p 53-56 7 refs

(A70-20626)

Description of the types of materials currently used for plastic encapsulation of semiconductor devices as well as methods for fabricating these devices. The long term performance of these devices under a variety of conditions including operating, storage, and humidity life are evaluated. The remaining problems prior to general acceptance and useage of plastic encapsulated semiconductors are considered. IAA

Review: This topic is vital to reliability and design engineers especially in the military but also for consumer and industrial gear. This article is largely a summary of previously published material, although no reference is made explicitly to the RADC work on this topic (see, for example, R69-14641). Unfortunately, reference 6, which gives some data has no source listed; merely an asterisk which does not go anywhere. The author, in a private communication, has indicated that the asterisk next to reference 6 should have referred to the same item as given for reference 1, i.e., DoD/NASA/Industry Meeting . . . Additionally on reference 6, Bard should read Baird. Apparently the study referred to in the conclusions as "this study" is largely a literature review since the author reports no new data. The presentation is reasonably balanced; he acknowledges that some of the plastic encapsulated devices have been very good and if they were representative, then there would be no problem. But he then raises the question (not often referred to by the manufacturers) of the bad results that some people have obtained with certain tests. The author wisely considers the fact that we have no laboratory tests that duplicate field experience, and that some of the arguments about interpretation of laboratory tests are pointless until we do have that field experience. (Similar material was presented in the paper covered in R70-15019 by another member of the author's organization.)

R70-15351 ASQC 837

AN INTERACTIVE COMPUTER APPROACH TO TOLERANCE ANALYSIS

Dorothea M. Bohling and Lawrence A. O'Neill (Bell Telephone Labs., Inc., Holmdel, N. J.) IEEE *Transactions on Computers*, vol. C-19, no. 1 Jan. 1970 p 10-16 4 refs

An interactive technique for statistical tolerance analysis has been developed for a computer with graphic display. The computer program called TAP provides for random perturbation of parameter values, repeated evaluation of system performance, and display of distribution histograms. Two applications are discussed to illustrate the adaptability of the technique to either linear or nonlinear problems. The digital simulation of an active circuit is used to show how the interaction with graphic display saves time in evaluating alternative designs. A hybrid simulation of an equalizer for a digital transmission system illustrates that complex time domain problems can be economically analyzed using TAP. In addition, it is shown how TAP is used to measure the reproducibility of an analog simulation. Author

Review: An important part of reliability analysis is to evaluate the effect of parameter variations on the performance of the manufactured product. This paper gives a general description of an approach which has been programmed on a computer; the program itself is not given. Presumably more information can be obtained from the authors. No mention is made of the capital costs involved in setting up such a computer program, since an existing general purpose facility was used. One of the main points is that by observing the results directly as they are derived, one can interact and terminate an analysis much more quickly than one could under some historically assigned criterion, and therefore this overcomes one of the big objections to the Monte Carlo approach. The program

does not give any indication of the sensitivity of the system to particular components; that is, if the spread is too wide, there is no way of knowing which of the components are contributing most to the spread except by trial and error. If there are many components, this would become quite tedious unless the interactive capability is used to acquire relative sensitivity before detailed investigations are performed. Thus, in circuit design, sensitivity analysis is usually equally important with a tolerance analysis. Nevertheless, this paper is an important step forward in the useful application of computers to system design. Any interested user should, of course, investigate the economics of the situation.

R70-15358 ASQC 831
SYSTEM RELIABILITY PREDICTION
C. M. Ryerson (ed) *Microelectronics and Reliability*, vol. 9, no. 2 Mar. 1970 p 81-82

The major need in system reliability prediction is seen to be management's ability to generate accurate predictions with full understanding of their meaning for optimum program use. Common factors leading to inaccurate predictions are analyzed. These include an unfamiliarity with reliability specialty jargon and the premature application of detailed prediction techniques prior to the availability of all the necessary information needed to made the techniques accurate. Numerical prediction and assessment of program conditions is described as another technique in need of expert study, understanding, and application. Problems peculiar to reliability physics, a new specialty area dealing with the basic physical and chemical reasons for degradation and failure, are discussed; primarily, difficulties are believed to arise when the reliability engineering aspects of reliability physics are not understood. The suggestion is made that management become more expert in the details or reliability. P.R.F.

Review: This is a good article on reliability prediction for systems. It reads easily; it is clearly and well written, and it is short — virtues which are all too rare. It is perhaps, at least nominally, directed more toward system managers than it is toward reliability engineers, but many of the latter need this message just as well as the former. The author is well known in the reliability field; in this article, he shows the reader a perspective gained from his many years. It is recommended reading for all of those whose work involves reliability specification and prediction.

R70-15369 ASQC 830
Army Electronics Command, Fort Monmouth, N. J. Electronic Components Lab.
POWER SOURCES FOR LONG ECONOMIC LIFE COMMUNICATIONS EQUIPMENT
Galen R. Frysinger Jul. 1969 19 p
(N70-13293; AD-693847; ECOM-3154) Avail: CFSTI

Because of the extended life and operating endurance of new electronic communications equipment, new power sources must be designed and developed which provide no-break operation and optimum costs over these extended operating periods. The concept of a rack-mounted power source as a utility tray component of an integrated shelter is described. Maintainability and life cycle costs are developed for silent static power generation systems in contrast to present engine-generator units. Author (TAB)

Review: This is a very brief presentation of the need for and characteristics of a long-lived generator of electrical power. It is so brief that no justifications for the numbers are given and some of the alternatives such as A, B are not clearly identified. The main value of the report then is in showing awareness of the need to consider reliability/maintainability factors and in showing that life-cycle costs can be estimated. Some other disadvantages of the paper are that none of the statistical assumptions are mentioned. The life (of the long-lived units) is only twice the MTBF (which means that the concept should be more fully explained). The time value of money is not considered although, since the lives are only a very few years, perhaps this is not important.

R70-15377 ASQC 831; 863
PROJECT ABLE
Irving Katz (Wright-Patterson AFB, Logistics Command, Ohio) *In: Proceedings of the 1970 Annual Symposium on Reliability, Los Angeles, Feb. 3–5, 1970* Symposium sponsored by the Institute of Electrical and Electronics Engineers, the Institute of Environmental Sciences, the American Society for Nondestructive Testing, and the American Society for Quality Control New York IEEE, Inc. 1970 p 84-93
(A70-32634) Avail: $8.00

Description of the ongoing Project ABLE (Acquisition Based on Consideration of Logistic Effects) directed towards creating tools which measure the logistic consequences of reliability and maintainability, and applying them to new weapon systems. The tools consist of formulae for total Logistic Effects (LE), comprising inventory spares, repairs, other logistic costs, system availability, and system dependability. The formulae are used initially by bidders to project Target Logistic Effects (TLE) which the government uses in the source selection process, and then again in an incentive structure. The latter would provide for a bonus or penalty based on the winning bidder's TLE and his Measured Logistic Effects (MLE), which are based on a predetermined test program. Throughout the life cycle of each new weapon system, the LE formulae can be used in establishing logistic requirements which are based on a cost/effectiveness analysis, and then repeatedly used in making tradeoff decisions, measuring progress, and forecasting future effects. IAA

Review: A model is presented in this paper for the purpose of quantification of all the consequences of reliability and maintainability efforts on a weapon system and of improving the decision-making processes based on such quantification. The equation presented is not very complex; however, the subject it is intended to model is very complex. The total logistic effects over a modern-day weapon system's full program life has to this point in time required complex treatment when the tradeoffs are analyzed quantitatively. This review, of course, applies to the model as described in the paper. The first task discussed is to establish a Target Logistic Effect (TLE) measure using a series additive model based on projected failure rates, repair rates, and facility utilization costs. A serious question arises in that the author notes that a bidder is to use the model to project TLE costs. Since a bidder can only use functional block diagram estimates of failure and generalized maintenance rates before he designs a product, the model requires the bidder to detail his entire development effort before he has contract. In order to fill the equation with numbers and to submit the quotation on time, there will be crash basis design, which typically results in later manufacturing, performance, reliability and maintainability problems. The same scope of subject matter was addressed by the Weapon System Effectiveness Industry Advisory Committee (WSEIAC) which produced a ten-volume final report (see R65-12200). Neither this milestone (WSEIAC) report nor any of the rest of the vast cost-effectiveness, cost-benefit, or systems analysis literature is referenced in this paper. The formula given in the paper results in a single dollar value. It is not clear how the weapon sys-

tem effectiveness measures (performance, reliability, maintainability, etc. or some function of them) relate to this simple formula. It would seem unlikely that all such requirements could be done away with. The paper does not state the type of weapon system for which the model is intended. There probably are variations in logistic-effect models for the different weapon-system types. Major cost items are not even mentioned in the paper, much less provided for in the model. Some of these are: regular handling-packaging and environmental protection costs; storage costs, shelf life considerations; losses due to storage error, pilferage, shipping damage, and variable administrative costs due to quantity of line replaceable units (LRU's) provided. There are no trade-off provisions between small LRU's and large LRU's. An approach whereby a government procurement agency undertakes to measure all the consequences of the reliability and maintainability efforts is sensible, long overdue, and a need recognized by many. This paper does not address realistically how the simple equation cited relates to meaningful and mutually acceptable specifications and contracts whereby the government will minimize total lifetime cost simultaneously with the contractor attempting to maximize profit. The paper does not mention whether the model has been implemented, nor if comments have been sought from contractors. It is difficult to imagine that the logistics effects model will be used jointly by government and contractors, from proposals through system testing, as described in this paper. In a private communication, the author has stated that Project ABLE has had very broad exposure to many professional audiences, and is evolving steadily in response to questions and critiques from these audiences. As a result, the present paper is not fully up-to-date. Those interested in thorough knowledge of the project should contact the author for additional material on the project.

84 METHODS OF RELIABILITY ANALYSIS

R70-15336 ASQC 844

FATIGUE STRENGTH OF STEEL IN BIHARMONIC VIBRATION

G. Z. Zaitsev and R. M. Faradzhov *Russian Engineering Journal*, vol. 49, no. 4 1969 p 8-10 4 refs

Experimental data from fatigue tests on 45-grade steel with stress concentrations and under loads superimposed with asymmetrical cycle are examined. Tests were also run under two loads with a symmetrical cycle. Author

Review: This paper deals with additively superimposed cyclic loading, a low amplitude high-frequency superimposed on a high-amplitude low-frequency load. This is, of course, different from the high-frequency amplitude's being modulated by a low frequency. The authors give several references to those who have done earlier work in this field but point out that the others have investigated the reduction of life rather than the reduction of allowable load at a given life. The authors investigate the situation at two lives, 10^4 cycles, and 5×10^6 cycles. Even though the data are for steels not used in this country, the results are of interest to research workers and possibly even to designers (they can get some idea of the effect if they have no other data on which to base their predictions.) The work described here is not far-reaching nor completely unexpected, but it does add a little bit to the fund of knowledge about fatigue.

R70-15337 ASQC 844

HOW COATINGS AND MATERIAL AFFECT SCREWED-JOINT LIFE

I. A. Birger et al *Russian Engineering Journal*, vol. 49, no. 4 1969 p 15-16 5 refs

The influence of thread clearance on the life of threaded joints was investigated using lubricating and matt coatings. The static strength of nuts made with a strong titanium alloy in place of steel was also studied. Charts and tables of test data are provided. P.R.F.

Review: This paper gives experimental results. It is concerned largely with the effect of modulus of elasticity of the nut and with the fit of the nut to the stud or bolt. The authors' conclusions are "reduced thread clearance and low-modulus nut materials increase the fatigue strength of screwed-joints considerably." For example, the authors suggest the use of strong titanium alloy nuts in place of steel nuts because titanium has a lower modulus than steel. Even though the particular alloys tested are not available in this country, the manner in which the results are presented will make them useful to designers. There are other considerations in designing a fastener system than simple fatigue, e.g., stress corrosion.

R70-15339 ASQC 844; 782

Martin Co., Denver, Colo. Research and Development Dept.

THE EFFECT OF ENVIRONMENT ON THE MECHANICAL BEHAVIOR OF MATERIALS Annual Report, Dec. 1967 – Dec. 1968

Irvin R. Kramer Dec. 1968 28 p refs

(Contract AF 49(638)-1455)

(N69-28789; AD-684580; MRC-69-39; AFOSR-69-0559TR)

Avail: CFSTI

The surface layer stress of high purity aluminum is lower in vacuum than in air. The relaxation rate, however, is faster in vacuum. The cyclic creep and work hardening rates of high purity and 1100 aluminum are lower in vacuum than in air. These observations are in accord with the concept that cyclic creep and cyclic hardening are controlled by the surface layer and not by the bulk of the material. Data on copper show that decreasing the surface layer stress increases the fatigue life. The difference in fatigue behavior in vacuum and air is caused by the difference in the surface layer stress. It is expected that the fatigue cracks will be initiated when the surface layer stress in a local region reaches a critical value equal to the fracture strength. Author (TAB)

Review: The title is overly general; a more appropriate one would have been, "The effect of vacuum environment on the fatigue behavior of metals." Reliability predictions involving materials require an accurate knowledge of the material properties in the operating environment. The purpose of this report is to describe an experiment which investigated fatigue testing under atmospheric pressure and compared the results with identical tests carried out at reduced pressure. The report is brief, but adequately discusses the experiment and the results. Additionally, the author proposes a theory to explain the effect that reduced pressure has upon the materials tested. (The report would have fitted the title better if the effect of increased pressure were also considered.) The information is clearly presented and will be useful to both test engineers and mechanical design engineers in helping to improve reliability.

R70-15342 ASQC 844

BASIC COURSE IN FAILURE ANALYSIS. LESSON 5: TORSIONAL FAILURE. LESSON 6: ADHESIVE AND

ABRASIVE WEAR. LESSON 7: PITTING AND SPALLING. LESSON 8: FRETTAGE, CAVITATION, AND CORROSION
Charles Lipson (Michigan University, Dept. of Mechanical Engineering, Ann Arbor, Mich.) *Machine Design* Dec. 11, Dec. 25, 1969, Jan. 8, Jan. 22, 1970 p 186-189, 74-77, 130-134, 152-157 1 ref

The final four parts of an eight lesson course on the basic failure mechanisms that must be considered in the design of any component are presented. These are: (1) Various types of torsional failures and their causes. (2) Adhesive and abrasive wear, and techniques to control them. (3) Design guidelines to reduce the effects of pitting and spalling and extend part life. (4) The causes and prevention of fretting, cavitation, galvanic corrosion, and stress-corrosion cracking. P.R.F.

Review: This is the last half of a series of articles entitled "Basic course in failure analysis." They can provide a good introduction to various failure modes and mechanisms and to the properties of materials which are important in controlling failures. This series applies largely to metals and to metal–metal contact. A solution for failures due to metal–metal contact such as wear is often achieved by replacing one of the metals with a plastic; for example, nylon on steel has very good wear properties whereas steel on steel may have very poor wear properties (both being nominally unlubricated). The same is true for some kinds of corrosion or fretting. Within the limitation of being restricted to metals, this entire series helps to provide the designer and reliability engineer with a knowledge of the complexities of failure and strength in metals. It is easy to get the impression, especially from advertisements in the steel industry, that strength is a matter of tensile strength; whereas very few parts in practice fail in a tensile mode. If one has assimilated the knowledge in this series, he can then ask himself how the material will respond to the very many aggravations it will receive in service and can proceed to design the part and recommend the fabrication and inspection so that a good, safe design life can be achieved. Another paper on a similar topic, but at a somewhat higher level of sophistication is "Preclude failure: A philosophy for materials selection and simulated service testing," by Thomas J. Dolan, in *Experimental Mechanics*, vol. 10, Jan 70, pp. 1-14 (see review in this issue of RATR).

R70-15346 ASQC 844; 782
INSULATION FOR SPACE
W. T. Starr (General Electric Co., Reentry Systems, Materials and reliability Engineering, Philadelphia, Pa.) IEEE *International Conference and Exposition, Mar. 1970, Paper* 21 p 15 refs

The high voltage frontier in space insulation is examined as it relates to unmanned vehicles such as the future multikilowatt Television Broadcast Satellite (TVBS). Included is a summary of some of the information presented at a Jet Propulsion Laboratory Conference on Voltage Breakdown in Electronic Equipment at Low Air Pressures. Literature on vacuum breakdown across insulating surfaces and through the vacuum is assessed. Outgassing characteristics of materials and the way that venting must be applied to insure that a good vacuum is present where it is needed are discussed. Author

Review: The attainment of highly reliable space systems requires much attention to be given to the problem of high voltage insulation. This paper reviews the historical development of insulation concepts for space application and covers general design techniques which might be employed to increase insulation reliability. The paper is largely tutorial and is directed mainly toward design engineers concerned with high voltage insulation. The content is technically sound and should be of most benefit to those engineers who are not familiar with the current literature in this area. Although the emphasis is upon space systems, the material is applicable to a wide variety of systems where good insulation techniques are necessary for reliability and safety.

R70-15348 ASQC 844
Lehigh Univ., Bethlehem, Pa.
SOME ASPECTS OF FATIGUE CRACK PROPAGATION
Richard Roberts and John J. Kibler Jul. 1969 32 p refs
(Grants NGR-39-007-011; NSF GK-1225)
(N70-12325; NASA-CR-66829)

The models of fatigue crack propagation proposed by Forman et al and Roberts and Erdogan were studied in this paper. By applying these models to existing data in the literature for thin 2024-T3 and 7075-T6 aluminum plates subjected to fluctuating tensile loads, it was found that both models gave comparable results when one considered just a gross correlation of the experimental data. By modifying Forman's model to incorporate the ideas of Roberts and Erdogan, a model was produced which appeared to be a more rational basis for studying the problem of fatigue crack propagation in thin plates and shells subjected to tensile loads, bending loads, or a combination of both. This fact was demonstrated for the case of thin plates subjected to fluctuating bending loads and for the case of thin cylindrical shells subjected to fluctuating internal pressure. Author

Review: There is a tremendous amount of study on crack propagation and, in particular, fatigue crack propagation. Eventually, it should result in the design of more reliable structures which use less material. Right now, the theories of crack propagation are not used extensively in practice except in a qualitative way. This paper contributes to the topic in two ways. First, it presents a vast body of experimental data which can be used for the evaluation of various theories, and secondly, it compares two theories and develops a modification thereof. The paper is reasonably easy to read. Unfortunately, the statistical aspects of the discussion are extremely brief. Two important points in which other analysts might be interested are the following. (1) The assumption is apparently implicitly made that the rms deviation is the same under all conditions; it would be worthwhile testing that assumption. (2) No estimates of the uncertainties in the various parameters are given. This is necessary in order to determine the relative importance of the various parameters. (There is apparently an error in the heading of Table 2; the column labeled $c \times 10^{-12}$ should refer to B instead.)

R70-15352 ASQC 844; 775
ULTRASONIC DETECTION OF INCLUSIONS IN STEEL
W. W. Bayre and D. D. McCormack (General Motors Corp., New Departure-Hyatt Bearings Div., Sandusky, Ohio) (*American Society for Nondestructive Testing, National Fall Conference, 29th, Philadelphia, Oct. 13–16, 1969.*) *Materials Evaluation*, vol. 28, no. 2 Feb. 1970 p 25-31 11 refs

Three methods of detection of nonmetallic inclusions in steel are discussed: the shallow stress wave for bearing component inspection; ultrasonic detection; and the bifocal compound lens, designed to permit optimum concentration of energy for detection

of minute discontinuities in cyclindrically shaped parts. Fatigue correlation studies and steel heat inclusion distribution patterns are also discussed. Author

Review: This is a good paper. The more that is known about the causes of failure and the means of separating poor parts from good parts, the more reliable equipment can be, or (for the same reliability) very often smaller parts can be used. The paper discusses explicitly the ultrasonic detection of inclusions in steels for bearings; the author very wisely points out at the end that for non-bearing applications, some of the methods presented in the paper can even be too sensitive; the inhomogeneities which are detected are not sufficient to reduce the life in many conventional applications (other than bearings). The description of the work being done within ASTM is very useful—many people do not realize the tremendous amount of effort required to turn a laboratory technique into a working standard. The development of nondestructive evaluation techniques is not diminishing in importance in aerospace industry, but is becoming even more important where high reliability at low cost is essential.

R70-15353 ASQC 844; 775

ACOUSTIC EMISSION AS A TECHNIQUE FOR NON-DESTRUCTIVE TESTING

Julian R. Frederick (Michigan University, Dept. of Mechanical Engineering, Ann Arbor) (*American Society for Nondestructive Testing, National Fall Conference, 28th, Detroit, Oct. 14–17, 1968.*) *Materials Evaluation*, vol. 28, no. 2 Feb. 1970 p 43-47 13 refs
(A70-21747)

A promising method for nondestructive testing and inspection is to observe the acoustic emission from materials when they are stressed. Observations can be made on tensile specimens or on manufactured parts. Except for the noise produced by crack nucleation or propagation, the exact mechanisms which cause acoustic emission are not clear at the present time. The amount of noise has been shown to be dependent upon microstructure and the level of the applied stress. The technique appears to offer considerable promise for the 'in-service' monitoring of critical structures. Author (IAA)

Review: This is a tutorial paper and can serve very well to introduce the research worker or reliability engineer to the field of acoustic emission. Some knowledge of metallurgical terms will help in understanding the article, but a great deal can be gained even without it. The work is very largely still in the laboratory stage; any field application would require extensive research and development. Nevertheless, it is a promising phenomenon; those who are not familiar with the field would do well to read this paper.

R70-15354 ASQC 844; 775

NONDESTRUCTIVE TESTING OF SMALL METAL TUBING

Harry W. Poole (Superior Tube Co., Quality Assurance, Norristown, Pa.) *Materials Evaluation*, vol. 28, no. 2 Feb. 1970 p 40A, 42A, 44A-46A
(A70-21748)

Review of nondesturctive testing of small metal tubing, the equipment and procedures for which have advanced to the point where a standard can be set that would reject all tubing offered. The improved nondestructive testing techniques (NDT) that have made it possible to inspect to the higher standards are also contributing to the solution of the manufacturing problems created by the standards. Eddy current testing, or electromagnetic inspection, is very fast, and is used in mass production. Some improvements in ultrasonic testing, such as development of the focused sound beam, are discussed. Both eddy current and ultrasonic testing use standard reference tubed with notches of predetermined size on the outside and inside surfaces near the center of the tube. Dye penetrant testing will show up defects that would otherwise escape visual inspection. The problems imposed by rigorous testing on the tube mill are considered. IAA

Review: This paper is labeled as a state-of-the-art review. It is very qualitative and makes considerable reference to the practices in the author's company. It will be a useful article for introducing the neophyte to the subject. It naturally contains little that is new to anyone involved with the field. The topic is an important one and one with which reliability engineers should be familiar. It will be a good article for them since it uses a negligible amount of technical jargon and does give a quick general review of the subject. Design engineers who specify small-diameter tubing should also be familiar with the contents of the paper since it introduces them to kinds of things they need to know for a failure modes, effects, and criticality analysis. There are no references to which one could go for further information, but the tables which show the characteristics of the kinds of tests available for small tubing will be helpful.

R70-15356 ASQC 844; 824

PRECISION OF RELIABILITY ESTIMATIONS

J. M. Grange and J. Dorleans (Engins Matra, Avenue Louis Breguet, Velizy, France) *Microelectronics and Reliability*, vol. 9, no. 1 Jan. 1970 p 59-69 29 refs
(A70-22019)

Attempt to improve the precision of reliability estimations. The causes of inaccuracy of the data used for reliability calculations are analyzed, and a simulation, using the Monte Carlo method, is made to evaluate the probability of valid predictions. The problem is treated from the standpoint of real equipment by making various assumptions about the distributions of failure rates. IAA

Review: It is not clear from the introduction of this paper in what perspective the authors have viewed reliability estimation. It is a tutorial state-of-the-art discussion on errors associated with estimating failure rates of systems. Most of the points have been discussed throughout the past decade or two so that there is little, if any, really new material here. It *is* put in a convenient form and, as mentioned above, provides a neat tutorial package. One would like to hope that such discussions as this are no longer necessary, but apparently that hope is forlorn. As the authors point out, it is easy to get so entranced with the accuracy of numerical calculations that one forgets not only the doubtful validity of the original data but also forgets that the applicability of the formulas themselves is in serious question. Newcomers to the field and new graduates from college must be continually reminded of this problem; occasionally, a manager may wish to be educated on the topic. For all of those people, this article is a good discussion of the topic. Some people have claimed accuracies within 10 or 20 per cent for their failure rate calculations on systems. In general, these will be ones wherein the data have been generated within the company and are applied to equipments quite similar to those from which the data were obtained. In this kind of situation, some of the uncertainties and errors in the methods tend to cancel out in going from the known equipment performance to the tabular data and then back to the similar equipment. In view of the discussion in the first part of the paper, it is this reviewer's opinion that one should not spend too much time on the distributional methods discussed in the latter half. (There is a very minor language problem.)

R70-15357 ASQC 844; 555

CALCULATION OF THE REQUIRED NUMBER OF SPARE PARTS

K. F. Tomasek (Research Institute of Telecommunication, Prague, Czechoslavakia) *Microelectronics and Reliability*, vol. 9, no. 1 Jan. 1970 p 77-78 3 refs

A nomogram is described for calculation of numbers of spare parts at probability $p = 0{\cdot}9$ and $0{\cdot}95$ that the cause of a system down time will not be a lack of spare parts of the determinate type. Author

Review: This technical note presents a nomogram for finding the cumulative sum of a Poisson distribution. The chart was not checked, but there is no reason to doubt its validity. Since the cumulative sum is related to the chi-square variable and tables of the chi-square function are ubiquitous, it seems more likely that one would happen to have at hand such a chi-square table than he would happen to have at hand this nomograph. One should be aware of the usual assumptions of the constant hazard rate (and the replacement rate's being equated to the hazard rate). There is, of course, nothing wrong with using a nomogram should one wish to do so. The cumulative sum of Poisson tables are sometimes designated as Molina's tables. Another source is the *Biometrika Tables for Statisticians* (E. S. Pearson and H. O. Hartley, Editors, Cambridge University Press, 1956, pp. 104-238). That table is arranged both in terms of the chi-square distribution and in terms of the cumulative sum of Poisson terms so that one need not know the chi-square relationship in order to use the table.

R70-15362 ASQC 844

FAILURE OF ALUMINUM CONTACTS TO SILICON IN SHALLOW DIFFUSED TRANSISTORS

J. Mc Carthy (The Plessey Co., LTD., Allen Clark Research Centre, Caswell, Towcester) *Microelectronics and Reliability*, vol. 9, no. 2 Mar. 1970 p 187-188 7 refs

The orientation sensitive, anomalous reaction of aluminum upon contact areas to silicon semiconductor devices is investigated. It is found that the evidence suggests the occurrence of a "Thermite" type reaction in which the exothermic reduction of SiO_2 by Al leads to Al/Si eutectic formation. It is stated that the large thermal capacity of the substrate and the local exhaustion of the reactants would arrest the reaction. Author

Review: The purpose of this paper is to present evidence for the occurrence of the reaction: $3SiO_2 + 4Al \rightarrow 3Si + 2Al_2O_3$ (1) during the sintering of silicon planar devices employing aluminum contacts. The sintering step is a short heat cycle in the 450°C – 550°C range which is empirically observed to reduce contact resistance and improve adherence. This paper shows that localized deep penetration (in excess of 0.5 μm) of (100)-oriented silicon is possible as a result of sintering. The model invoked to explain the penetration is the local occurrence of temperatures above the aluminum-silicon eutectic temperature of 577°C. The heat source to reach these temperatures in excess of the sintering ambient temperature is the exothermic reaction between Al and SiO_3 as given in (1). This hypothesis is strengthened by the demonstration that the anomalous deep penetration occurs only in the presence of a thin oxide layer on the silicon. Such thin oxides are present on all silicon surfaces except those which are specially cleaned or freshly etched. The author shows that freshly etched silicon, coated immediately with aluminum, does not produce the deep sintering pits characteristic of aluminized silicon not so prepared. The paper is brief but presents observations that could be of major importance.

R70-15364 ASQC 844

Hydronautics, Inc., Laurel, Md.

EXPERIMENTAL RESEARCH ON HIGH FREQUENCY FATIGUE AND DYNAMIC TENSILE TESTS AT ELEVATED TEMPERATURES

Andrew F. Conn and A. Thiruvengadam Jul. 1969 76 p refs (Contract NAS3-11168)

(N70-13495; NASA-CR-72618; TR-829-1) Avail: CFSTI

The effects of elevated temperature and high strain rate on fatigue life and tensile properties were measured for annealed 316 stainless steel and titanium alloy 6Al-2Mo-4Zr-2Sn in the solution heat treated and aged condition. A 14 KHz magnetostriction oscillator was used for fatigue testing. A split Hopkinson pressure bar provided dynamic tensile data up to 1300 F. The fatigue data were bracketed by Manson fatigue life predictions, based on static and dynamic tensile properties, although the dynamic prediction curves generally agreed better with data from the highest cycle tests. Creep effects were found to be negligible. Author

Review: This is a well-referenced report of what appears to have been some good experimental work. Apparently no attempt was made to compare the high-frequency fatigue results with those obtainable at low frequencies to find out whether or not the material was in the region of negligible effect due to frequency. Much of the data on the S–N curves show considerable scatter and thus a statistical interpretation would be necessary for any comparison. On the curve showing total-strain-range versus cycles-to-failure, all the points on each curve have virtually the same total strain range and the points cover three decades, again indicating that considerable statistical manipulation would be necessary in order to describe the results adequately. The introduction is marred with an example of the number of cycles of alternating load experienced by a turbine blade. Unfortunately for the example, a turbine blade does not experience one main cycle of alternating stress for each revolution of the engine, but rather the centrifugal stress changes only when the rpm changes. This kind of work is important for evaluating new and better materials for aerospace engines and in developing better theories which describe material performance in terms of properties which are easy to measure.

R70-15366 ASQC 844

Council of Scientific and Industrial Research, New Delhi (India). Aeronautical Research Committee.

ESTIMATION OF THE RATE OF PROPAGATION OF FATIGUE CRACKS

S. K. Bhandari and S. Ramamritham Aug. 1969 34 p refs (N70-16171; ARC-TN-3) Avail: CFSTI

Experimental data on fatigue crack propagation in aluminum alloy sheets obtained by a number of workers were analysed. An expression was derived for the rate of fatigue crack propagation in terms of the basic parameters of fatigue loading, material property and width of sheet. This agrees with the experimental observations of almost all the workers in the field. It was also found that the rate of crack propagation from initiation to final fracture is in three stages. The first stage extends from initiation of crack up to about 20 per cent of specimen width and consumes almost 80 to 90 per cent of the life of the specimen. The expression derived in this note is applicable to the first stage, which is the one of importance to designers and engineers. Author

Review: This paper on the rate of propagation of fatigue cracks can profitably be compared with "Some aspects of fatigue crack propagation," by Richard Roberts and John J. Kibler (N70-12325), which is covered in this issue of RATR. The present paper is entirely theoretical; that is, apparently the authors present no experimental data of their own. Work of this type is useful and its publication helps to keep everyone abreast of what is going on in this important

field. The separating of the crack growth process into three stages by its graph is dependent, of course, on the functions which are plotted. It is a worthwhile tentative hypothesis, but it would help if physical considerations could be reduced to show the different physical processes being hypothesized in each one of the cases. In the evaluation of the various parameters of a model from the data, it helps to estimate also the uncertainty in those parameters. One of the big advantages is that the unimportant parameters (with a set of data being fitted) then stand out. The state-of-the-art in conceptual models for the growth of fatigue cracks is still quite grossly empirical, with many people coming up with equally good (poor) models.

R70-15367 ASQC 844

Southampton Univ. (England). Inst. of Sound and Vibration Research.

HIGH AND LOW STRESS LEVEL FATIGUE FRACTURES IN MILD STEEL Summary Report

Matej Bily and Thomas R. G. Williams Wright-Patterson AFB, Ohio AFML Aug. 1969 22 p

(Contract F61052-68-C-0027)

(N70-15087; AD-695067; ISAV-Memo-259; AFML-TR-69-213) Avail: CFSTI

Fatigue fractures of mild steel under sinusoidal and random loading conditions have been investigated. The fractures can be divided into two groups; at low stresses the fatigue crack paths are transcrystalline and at high stresses they are both transcrystalline and intercrystalline. The transition occurs over a narrow stress range and is associated with a discontinuity in the S/N curve. This discontinuity involves the onset of yielding at the root of the notched specimens and the yield point in cyclic loading correlates with yielding in monotonic straining. Author (TAB)

Review: This paper analyzes the discontinuity in the fatigue curve in a reasonably conventional way. The discontinuity is not entirely obvious from looking at the S–N diagrams since they could be interpreted in more than one way, especially with the considerable scatter involved (Figures 1 and 7). In interpreting the experimental data, one must be careful to distinguish between two approaches: (1) whether or not the data can be said to fit the model reasonably well, and (2) whether the data forcibly imply the model. In this case, the data points do not forcibly imply the model, but they probably can be shown not to be inconsistent with it. It would have been interesting to keep track of the two different kinds of cracking and draw a fatigue curve for each. It is also not clear why the random fatigue tests should show the discontinuity clearly since presumably no matter what the nominal load, some of the peaks are above the critical stress and some are below it.

R70-15368 ASQC 844

National Aeronautics and Space Administration. Langley Research Center, Langley Station, Va.

EFFECT OF STRESS RATIO ON FATIGUE-CRACK GROWTH IN 7075-T6 AND 2024-T3 ALUMINUM-ALLOY SPECIMENS

C. Michael Hudson Washington Aug. 1969 31 p refs

(126-14-15-01-23)

(N69-34704; NASA-TN-D-5390) Avail: CFSTI

Axial load fatigue crack growth tests were conducted on 12 inch-wide sheet specimens made of 7075-T6 and 2024-T3 aluminum alloy. These tests were made at stress ratios R (ratio of the minimum stress to the maximum stress) ranging from -1.0 to 0.8 and at maximum stress levels ranging from 5 to 50 ksi to study the effects of stress ratio on fatigue crack growth. The experimental results were analyzed by using the stress intensity method. For a given positive stress ratio, the fatigue crack growth rate was a single valued function of the stress intensity range for both 7075-R6 and 2024-T3 aluminum alloys. For $R \geq 0$ the crack growth rates varied systematically with R for both materials; the higher stress ratios produced higher rates of fatigue crack growth for a given stress intensity range. Fatigue cracks in the 7075-T6 aluminum alloy grew at the same rates in all tests with $R \leq 0$ when the same maximum stress intensity factor was applied. In contrast, fatigue cracks in the 2024-T3 aluminum alloy grew faster in the tests with $R = -1$ than in the tests with $R = 0$ when the same maximum stress intensity factor was applied. Empirical equations previously developed by various investigators were fitted to the experimental data. In general, good correlation was obtained. Author

Review: This report deals with two important aerospace alloys and is concerned explicitly (as the title points out) with the effect of stress ratio on the growth of fatigue cracks. The experiments appear to have been well conceived and well carried out and are adequately reported and discussed. The report can be useful to designers, but it is more likely to be of value to those engaged in research toward developing more adequate models for fatigue. Another report which deals with crack growth vs. the stress intensity factor and models relating these two parameters is "Some aspects of fatigue crack propagation," by Richard Roberts and John J. Kibler (N70-12325), which is covered in this issue of RATR.

R70-15371 ASQC 844

Boeing Co., Renton, Wash. Commercial Airplane Group.

STAINLESS STEELS CAN BE STRONG AND TOUGH

Donald Webster Aug. 1969 12 p

(Contract N00014-66-C-0365; ARPA Order 878)

(N70-15594; AD-695795; D6-24379) Avail: CFSTI

The competitive position of high strength stainless steels in the aerospace industry is reviewed in light of the significant improvements in mechanical properties that have been achieved in the past year. Author (TAB)

Review: This article is a good illustration of the way in which many different failure modes of a metal should be considered in an application, and of improving the resistance to those failure modes so as to improve the product. Since the paper is an enthusiastic exposition of the benefits of this new treatment of a stainless steel, it is very helpful that the author points out a failure mode which has not been improved (embrittlement at high temperatures). There are no comparisons of costs relative to the other construction materials. It is also not yet known how robust these properties will be in terms of the treatment the material actually receives during ordinary manufacture and use (not everyone always does everything according to the rules). In view of the nickel shortage, it is noteworthy that this alloy does not contain nickel. In summary, this paper is worth reading by reliability engineers regardless of their specific interest because it shows the kinds of things that ought to be considered in evaluating a metal (besides merely the room temperature tensile strength).

R70-15374 ASQC 844

California Univ., Berkeley. Lawrence Radiation Lab.

FATIGUE LIFE GAGES ON A 46000 KVA GENERATOR UNDER PULSED LOADING

Roland S. Krevitt Aug. 1969 63 p refs

(Contract W-7405-eng-48)

(N70-19548; UCRL-18423-Rev) Avail: CFSTI

On December 19, 1966, near catastrophic fatigue failures in

two 46,000-kVA generators were discovered; a 6-month shutdown of a major nuclear physics research facility resulted. The cost of replacing the failed parts was $330,000. The Bevatron is a proton accelerator. A large electromagnet guides the protons in a circular path, and because of the nature of the acceleration cycle, the magnet must be pulsed 11 times per minute with a peak coil current of 8,400 A and a peak voltage of 16,000 V. This results in a pulsed demand on the generators that supply power to the electromagnet, and causes severe stress in the generator armatures. These cyclic stresses led to fatigue failures. The use of S/N fatigue life gages to detect possible future armature fatigue damage is described. Author (NSA)

Review: This is a good paper. It is a very practical, pragmatic one which describes the experiences of the author when trying to solve a fatigue problem. It will be especially helpful for younger engineers who tend to have a feeling that this kind of problem can be solved by a brief straightforward application of technology, whereas in fact many of the difficulties that arise are unrelated to the technology of fatigue. They are the kind of difficulties that do cause many people-problems in trying to improve the reliability of their equipment. The paper will contain little of value for those doing research except to show them what a real, every-day problem is like. (The large-print title on the microfiche has a misspelling—it should be "Fatigue Life Gages . . .", not "Fatigue Life Gases . . .".)

R70-15375 ASQC 844
Iowa Univ., Iowa City. Dept. of Mechanical Engineering.
MICROSCOPIC MOVIE OF FATIGUE INDUCED CRACK INITIATION AND PROPAGATION
R. E. Duncan and R. I. Stephans Aug. 1969 9 p refs
(Contract DAAF03-69-C-0014)
(N70-20320; AD-698017) Avail: CFSTI

A motion picture taken through an optical microscope was made in an attempt to better understand the mechanisms of fatigue crack initiation, propagation and fracture in metals. The primary usage of the movie is that of a visual education training aid. The movie qualitatively compares crack initiation and propagation in a low carbon steel under the following conditions: (a) low cycle fatigue (less than 50,000 cycles to failure) photographed at 16X, 150X, and 300X magnification; (b) high cycle fatigue (about 1 million cycles to failure) photographed at 300X magnification. Under these conditions the movie shows the interaction of slip lines, slip bands, crack tip, grains and grain boundaries under cyclic conditions. Author (TAB)

Review: This paper describes the types of things the movie shows and it points out that the movie is largely pedagogical (as opposed to one showing new research results). Unfortunately, the paper does not say how one might obtain copies of this movie. However, the second author has indicated, in a private communication, that review copies can be obtained from Professor Ralph I. Stephens, Mechanical Engineering Department, University of Iowa, Iowa City, Iowa 52240. Personal copies may *then* be purchased from the Audio-Visual Aids Department, University of Iowa, Iowa City, Iowa 52240. As the authors do point out, fatigue is one of the most important mechanical modes of failure. Therefore, movies such as this can give designers, who are otherwise not as familiar with fatigue as they ought to be, a better appreciation of the fatigue problem. With this better appreciation and deeper understanding, they may be more conscientious about considering the fatigue failure mode in their designs. Showing the difference between high-cycle fatigue and low-cycle fatigue is very worthwhile especially since the designers' response to each will be different. The specimens were notched low-carbon steel, a very common type of structural material. One should, of course, distinguish this movie from those aimed at furthering research purposes by carefully investigating and illustrating phenomena which have not hitherto been directly observed.

85 DEMONSTRATION/MEASUREMENT

R70-15360 ASQC 851
EQUIPMENT RELIABILITY AND THE ENVIRONMENT
J. Harris (Decca Radar, LTD., Croyden, Surrey) *Microelectronics and Reliability*, vol. 9, no. 2 Mar. 1970 p 145-156

*The problems of reliability in commercial marine radar equip*ment encountered in the past 15 years, and the efforts made by one company to improve the reliability of their product are described. Principles developed by the Advisory Group on Reliability of Electronic Equipment (AGREE) are utilized to improve the reliability of equipment in service. This improvement is achieved by removing inherent weaknesses from the design during the prototype and preproduction stage and by monitoring new equipments from the factory for the whole period during which the equipment is in production. It is reported that this method has reduced the annual servicing cost to the customer and has reduced the company's guarantee account (per equipment) by an amount which more than pays for the operation. Author

Review: This is a good paper (although different and more pertinent than might be inferred from the title). It deals largely with the efforts of an industrial company to manufacture reliable radars for commercial shipping use. The company is using AGREE-type testing (not contractually required). The author makes a very pertinent point in that he feels the AGREE-type testing they do is more than paid for by reduced warranty costs. He also gives a useful conversion factor, namely, the MTBF during their AGREE-type testing is 15 to 20 per cent of that observed in the field. He furthermore shows by example that the AGREE-type testing during pre-production will not find all the defects. This is because the components are not purchased in the large quantities in that period that they are during production; thus, one may be receiving different parts during those two times. In his particular illustration, the defect in production parts was caught during the production-AGREE testing and saved an appreciable number of field fixes that would otherwise have had to be made. The two appendices on the details of the AGREE testing and on analyzing the reliability of marine radars add to this valuable case history. In several places, the author refers to an internal document which lists the hazard rates observed for components and subsystems in the radar; it certainly would be useful information to publish (but is undoubtedly regarded as company-secret). There is virtually no discussion of the management aspects of reliability except by implication. Obviously, this kind of testing would not be done unless management were well behind it. The author has also given experimental confirmation of Drenick's result: after a long period of time, the times between repair actions will be exponentially distributed; that is, the repair rate will be a constant and there is no wearout period (under the assumptions of the derivation). (In the introduction, the author strays from his main point, but the paper quickly settles down to a good case history description.)

87 MAINTAINABILITY

R70-15341 ASQC 871
COMPUTER AIDS OPTIMIZED MAINTENANCE
James A. Trotter, III (E. I. du Pont de Nemours and Co., Sabine River Works, Employee Relations, Orange, Tex.) *Instrumentation Technology*, vol. 17, no. 2 Feb. 1970 p 40-44

It is reported that where a computer system helps to optimize and schedule preventive maintenance, there is a sharp reduction in instrument maintenance workload and an improvement in instrument utility. This preventive-predictable maintainance technique is explained, along with its application to critical instrumentation and how the program can reduce maintainance costs. Author

Review: This paper reports on what appears to be a good maintenance program. Many of the details have been programmed for a computer; the program itself is not described although apparently a great deal of time and effort went into it. The idea of dividing the instruemnts into two groups, one critical and one not critical, seems to be very constructive. The non-critical group have no preventive maintenance so that their experience can be used to give direct mortality statistics. These are then used to determine the optimum preventive maintenance intervals on the critical instruments. One of the big problems in any large plant is that the maintenance workers themselves often feel that they know infinitely more about their work than do "the people in the front office." Apparently, this system was devised to take that "blue collar" experience into account and turn it to the advantage of the system, not only technically but psychologically as well. The system obviously has application to other than strictly instrument maintenance, maintenance activities will profit from being familiar with this project.

R70-15355 ASQC 871; 851; 862; 873
OVERSEAS AUTOVON MAINTAINABILITY FIELD TRIAL
N. J. Elias (Automatic Electric Labs., Inc., Northlake, Ill.) (*Automatic Electric Technical Journal, vol. 11, no. 5, Jan. 1969.*) *Microelectronics and Reliability*, vol. 9, no. 1 Jan. 1970 p 51-58 5 refs

The concept of maintainability is introduced as a vital factor in the design, development, and operation of modern communication systems. A maintainability demonstration on a Station Technical Control facility that is part of the Overseas AUTOVON System is discussed as an introduction to some of the maintainability concepts. P.R.F.

Review: This is a good description of a maintainability-test case history. A good background for the problem is presented and then the test itself is described. Maintenance of equipment is an important part of keeping it reliable, and quantitative specifications for maintainability will become even more popular in the future. The paper will be especially valuable for reliability/maintainability engineers who will be faced with similar demonstrations. Actually, people on the other side of the fence are equally concerned, namely, contractors who wish to specify such demonstrations and to supervise them.

R70-15372 ASQC 872; 824
Florida Univ., Gainesville. Dept. of Industrial and Systems Engineering.

OPTIMUM AGE REPLACEMENT IN THE BIVARIATE EXPONENTIAL CASE
R. L. Scheaffer Aug 1969 21 p refs
(Contract DAHC04-68-C-0002; Proj. Themis)
(N70-22415; AD-697786; Themis-UF-TR-27; TR-27; AROD-T-1-40-RT) Avail: CFSTI

A system is assumed to contain a pair of units operating in parallel. A pair of units need not be replaced immediately upon the first failure, but both units in the pair are to be replaced (or repaired) at the same time. An optimum age replacement policy is found for the case in which the pair has a bivariate exponential life distribution. Author (TAB)

Review: This paper is a practical application of a bivariate exponential distribution. It is presumed, of course, that one knows the various parameters of the distribution. There is no mention of estimating them from the data or what would be involved because of their uncertainties. The results are interesting; they are potentially useful only insofar as one may know the joint parameter; it is not one whose value is traditionally known (other than zero). The derivations themselves are quite straightforward; the time value of money is neglected as is the extra cost of downtime. (This paper treats a special case of the bivariate exponential distribution which was discussed in Project THEMIS Technical Report No. 22, which is also reviewed in this issue of RATR.)

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS VOLUME 10 NUMBER 11

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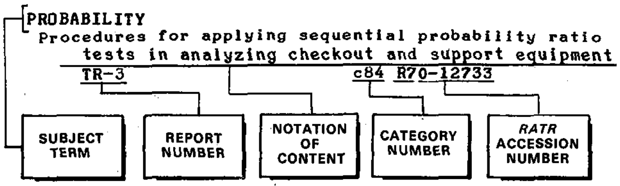

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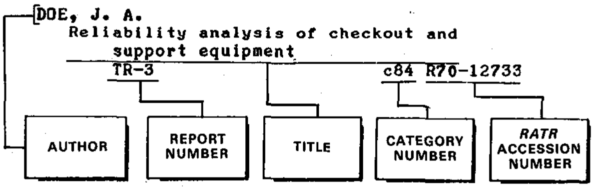

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DECEMBER 1970

Volume 10
Number 12

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SPECIAL NOTICE

Budget and personnel stringencies make it necessary for NASA to discontinue *Reliability Abstracts and Technical Reviews (RATR)* at the end of this calendar year.

Publication of *RATR* will cease with issuance of the Annual Index for January–December 1970.

There are no plans to institute any similar type publication.

Reliability and Quality Assurance Office
National Aeronautics and Space Administration

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The second section of *RATR* contains four indexes: The Subject Index is to assist in scanning or searching the literature on specific topics. The Personal Author Index identifies the publications of specific authors. The Report and Code Index is a listing of the report numbers of items abstracted and reviewed in the journal; this index also includes a listing of the ASQC codes for identifying the *RATR* accession numbers of the items to which the codes have been assigned. The Accession Number Index identifies the categories in which the abstract-reviews appear in the journal. Cumulative indexes are published annually.

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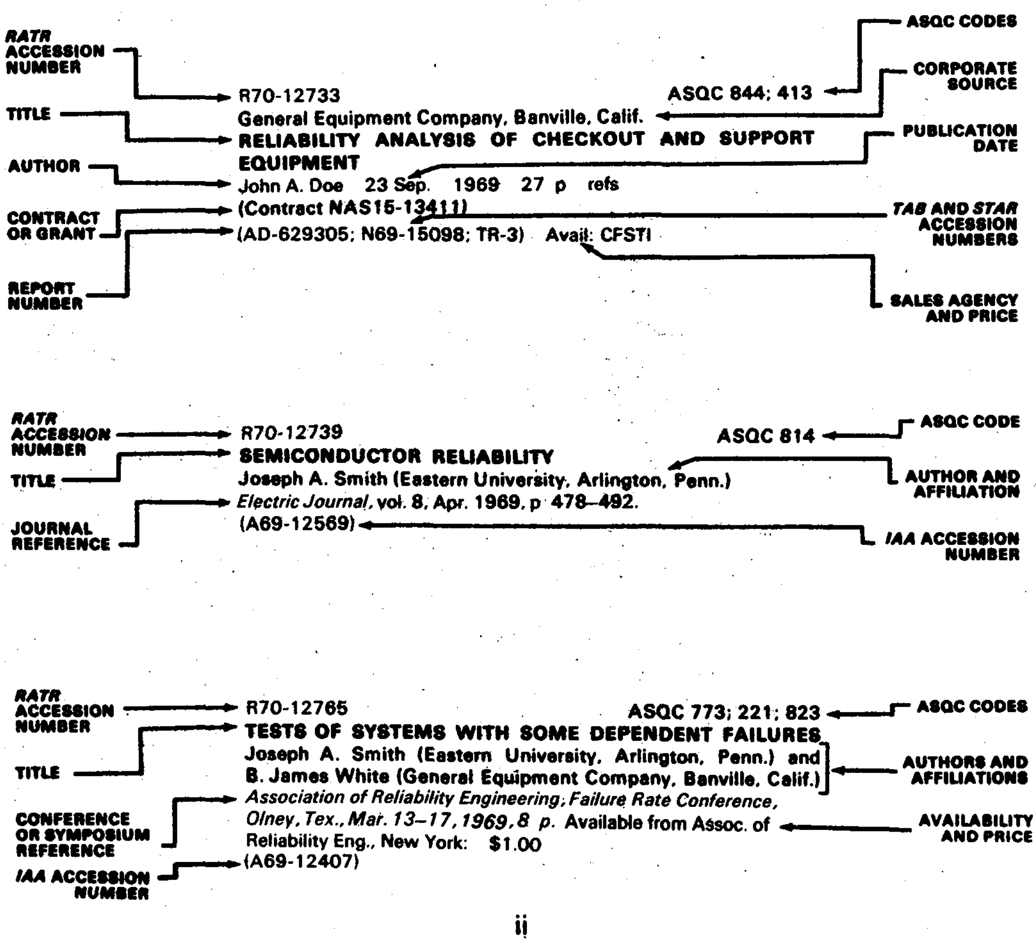

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Reliability Abstracts and Technical Reviews

A Monthly Publication

of the National Aeronautics and Space Administration

December 1970

81 MANAGEMENT OF RELIABILITY FUNCTION

R70-15394 ASQC 817; 871

MAINTAINABILITY TRADE-OFF DECISIONS

R. W. Kane (Thermo King Corp., Reliability and Quality Control, Bloomington, Minn.) *American Society of Mechanical Engineers, Design Engineering Conference and Show, Chicago, May 11–14, 1970, Paper* 4 p 2 refs

(ASME 70-DE-37) Avail: $1.00 members; $2.00 nonmembers

Design trade-off studies are discussed with particular emphasis in the area of maintainability trade-offs. Maintainability is considered in two categories: scheduled or preventive maintenance, and off-schedule or corrective maintenance. Commercial product examples are cited. P.R.F.

Review: For those design and reliability engineers who are not familiar with the problems of adequate maintenance, this is a good paper for reminding them of its importance. This is another field where, if we only were doing as well as we now know how, maintenance would be much easier on virtually all equipment. Studies by the Navy have shown that identical failure modes which could be prevented by proper design have occurred in aircraft from the beginning of the time the Navy has had them. In some way or other, this fount of practical experience must be transmitted from generation to generation of designers. Also, of course, a designer who has skinned his knuckles repairing machinery is much more likely to design for ease of maintenance than is one who has a more ivory-tower view of the situation. The greasy view may be somewhat contrary to those whose idea of a professional is one who sits at his desk and makes calculations and gives orders, but it is always nice to have on the design team a few men of whom the service department is proud. In some situations it is not economically feasible to design-in a high reliability, and this paper points out the realities of those situations.

R70-15416 ASQC 810; 844

GE/RESD FAILURE ANALYSIS SYSTEM

William J. Maloney, Jr. and Lloyd M. Crumley (General Electric Co., Reentry and Environmental Systems Div., Philadelphia, Pa.) *In: Proceedings of the Third Annual Seminar on Failure Analysis, University of Pennsylvania, Philadelphia, May 21, 1970* Sponsored by the Institute of Electrical and Electronic Engineers May 1970 p 11–22

Avail: $5.00

A failure control system encompassing three stages, i.e., reporting, analysis, and correction, is described. It is noted that each stage, by its relationship to the previous stage, provides an opportunity for a management decision concerning the need for additional attention or re-evaluation of the previous decisions. Each stage includes a form which structures the stage and provides impetus and visibility to the actions taken during the stage. Management of the failure control system is seen to involve those efforts which provide managers with the data necessary to evaluate whether or not the failure situation on the program as a whole is in satisfactory condition; the devices which provide this overview are described. P.R.F.

Review: This paper deals with the management system which oversees knowledge about and correction of failure. It is generally a good paper; there are several examples which help to illustrate the authors' points. In applying this kind of management system to other companies, care needs to be taken that the size of the effort is in accord with the size of the problem. The authors point this out as one of the benefits of their system, during the course of their explanations of the need for it, but in the description of the system itself it is easy to envision (wrongly) a large cumbersome affair with many meetings accomplishing nothing but wasting time. The system as described attempts to minimize these cumbersome ritualistic procedures by appropriate management controls. In some ways, this is in contrast to management schemes which have been proposed in which it appeared that every failure was given extremely heavy attention and that an unwieldy burden was placed on the project. The success of the described system depends, of course, on the ability of managers to place things in good perspective and not to make decisions on the basis of what they hope will happen but on what they expect to happen.

R70-15436 ASQC 810; 770

DANGERS AND POTENTIALS OF SMALL QUANTITY TESTING

Thomas A. Budne (Product Assurance Consultant, Great Neck, N. Y.) *In: Proceedings of the 1970 Product Liability Prevention Conference, Newark, N. J., Aug. 26–28, 1970* Sponsored by American Society of Quality Control, American Society of Safety Engineers, Institute of Electrical and Electronic Engineers, and Newark College of Engineering American Society for Quality Control, Inc. 1970 p 81–87

The relative merits of small and large quantity testing are considered as they relate to product reliability. Fundamental considerations which apply generally to all testing, and special considerations which apply to reliability testing, are discussed. Author

Review: The paper discusses what can be gained from various kinds of testing and what is often not known as the result of a particular test. Thus, the paper is actually more useful and more general than the title indicates. Testing is very important from a reliability and safety point of view, especially where statistical uncertainties are involved. The author also points out areas in which testing is important even in the presence of small uncertainties but high complexity. In the allusion to statistical techniques, largely involving Weibull graphical analysis, the data points are manipulated in order to achieve a straight line. One should be especially careful about what he thinks such manipulation has proved. There seems in many places to be a considerable amount of magic assurance associated with the exponential distribution (the author refers to it as the 45° slope on the Weibull plot) which is not justified. The author makes many good points about situations wherein testing is useful. Properly designed tests (which need not include statistics) can often locate the source of troublesome defects. Much of the paper is non-technical (in fact, the best parts of the paper are non-technical) and can be easily read and understood by managers and others who are not familiar with the technical jargon.

R70-15437 ASQC 812

A BIG STEP UP TO TOTAL RELIABILITY

Adolph Hitzelberger (Motorola Corp., Franklin Park, Ill.) *In: Proceedings of the 1970 Product Liability Prevention Conference, Newark, N. J., Aug. 26–28, 1970* Sponsored by American Society for Quality Control, American Society of Safety Engineers, Institute of Electrical and Electronic Engineers, and Newark College of Engineering American Society for Quality Control, Inc. 1970 p 117-131

A case history of a program designed to achieve total product reliability is described. It is felt that quality control and reliability techniques are advanced by blending existing technical know-how with statistical aids. The objectives of this blending are twofold: to probe for product weaknesses earlier in the development cycle to force failures or malfunctions in test problems that previously have only shown up in the field; to accelerate the process of completely avoiding these problems by an insistence on the identification of the cause. The course covered statistical fundamentals, failure prevention techniques, identification of real cause and effect relationships, strategies for finding unknown causes, and lectures on the mathematics of reliability. P.R.F.

Review: This excellent paper is a case history. Supportive material describing a training program conducted within the company with actual problems solved is described, using the problems as the vehicle for presentation. The purpose of the paper was to present an overview, a general paper describing reliability to a group of non-engineers. As such the paper offers little new but is excellent reading for managers and non-industrialists interested in reliability. It is unfortunate that the author did not include references or suggested reading for his readers. A previous paper by the author (see R68-13656) may be useful in evaluating the progress made in the intervening years. The paper covered by R63-10815 may also be of assistance to the reader in seeing another approach to the same task.

82 MATHEMATICAL THEORY OF RELIABILITY

R70-15384 ASQC 824; 553

Watervliet Arsenal, N. Y. Benet R and E Labs.

TABLES FACILITATING CONFIDENCED RELIABILITY CALCULATIONS FOR THE NORMAL OR LOGNORMAL DISTRIBUTION

Royce W. Soanes, Jr. Aug. 1969 29 p refs

(N70-11693; AD-693265; WVT-6937) Avail: CFSTI

Small sample size tables are presented which facilitate reliability--mission life calculations at a given confidence level. The tables are calculated using the exact sampling distribution of the normal reliability estimator. A computer program is included which will enable one to calculate more extensive tables for different sample sizes and confidence levels. Author (TAB)

Review: The author has solved a vexing problem in reliability and has prepared a few tables which illustrate the use of his formulas for the most-used values. The tables are for confidences of 95% and 90% (one-sided lower bounds). More importantly, he gives a copy of the program source-list; it appears to be written in a FORTRAN dialect. The reference below by the same author derives the equations which are solved for these tables [1]. Engineers who are familiar enough with the problem to understand it will be able to use the results as reported.

Reference: [1] Royce W. Soanes, Jr., "Confidenced normal and lognormal reliability for any sample size," Watervliet Arsenal Technical Report WVT-6910, Apr 69.

R70-15388 ASQC 824; 844

British Steel Corp., London (England). Inter-Group Labs.

THE APPLICATION OF TIME-TEMPERATURE PARAMETERS FOR THE PREDICTION OF LONG TERM ELEVATED TEMPERATURE PROPERTIES USING COMPUTERIZED TECHNIQUES

R. P. Harvey and M. J. May 1969 21 p refs

(MG/Q/183/69)

A computer based system for the processing of large amounts of creep-rupture data is briefly described. The practical problems encountered in attempting to provide accurate creep-rupture strength values for material specifications are considered, with particular reference to the selection and application of time-temperature parameters for extrapolation. Experience with the use of a computer method for optimization of the constants of the generalized equation of Manson and its application to different steels and conditions of test data, are described. The influence of testing errors,

and metallurgical features on scatter and extrapolation difficulties are considered and preliminary results of a statistical survey of prediction accuracies are presented. Author

Review: This is a good discussion of the statistical and experimental problems associated with prediction of creep rupture. Not only is it difficult to fit everything into one simple formula, but the quality and quantity of the data also cause problems. This is not an elementary discussion nor a tutorial one. An appreciable familiarity with creep rupture and some of the problems associated with its prediction are necessary for easy understanding of the report. It is not entirely clear that the computer program is designed to give the uncertainty in the 100,000 hour prediction as well as the point estimate. There are two kinds of uncertainty: (1) the uncertainty of the mean line itself, and (2) the tolerance band to be expected from all the specimens. While one would like to have a great deal of 20,000 hours is two and one half years. A six months (4,000 to 5,000 hours) point is much more likely a maximum limit for many of the materials in view of the high costs of experimental equipment and of running the tests (especially uninterrupted tests). It is good to see this kind of attention being given to the prediction of long-term creep rupture since there have been cavalier treatments of the subject in the past, especially on an individual company or society level. Furthermore, the emphasis on proper design of the experiments (to facilitate statistical analysis) is well placed.

R70-15391 ASQC 824; 844

FATIGUE ANALYSIS DUD TO RANDOM LOADING WITH APPLICATION TO COMPLEX STRUCTURE

I. A. Hassoun (Dana Corp., Engineering and Research Div.,Taylor, Mich.) *American Society of Mechanical Engineers, Design Engineering Conference and Show, Chicago, May 11–14, 1970, Paper* 8 p 34 refs

(ASME 70-DE-14) Avail: $1.00 members; $2.00 nonmembers

The case of an elastic beam subjected to random loading is analyzed to give the essential information needed for fatigue analysis of complex structures. The stress mean square is evaluated and a general expression is developed which can be used in any of many cumulative damage concepts to predict the fatigue life. The peak crossing technique is used in a new modification to Miner's cumulative damage concept. Author

Review: This is a theoretical paper, a large portion of which is devoted to basic theoretical concepts in the analysis of random variables, in particular, those associated with correlation and power spectra. The linear theory of cumulative damage is modified somewhat but not to account for past history. The paper will be of most value to those with some experience in the field who wish to know what others are doing and thinking. It will be of little use directly to designers or reliability engineers; it will be of more value to those engaged in fatigue testing. It is important to remember one of the author's final options, namely, that if a theoretical analysis is impossible, one resorts to empirical and experimental analyses. In any complex situation, this must virtually always be done. The theoretical analysis just shows general trends and directions in which one might go. See, for example, the comments in the paper, "Local stress-strain approach to fatigue analysis and design," by Topper and Gowda, which is also reviewed in this issue of RATR.

R70-15396 ASQC 824

RELATING PROBABILISTIC METHODS TO RELIABILITY CONSIDERATIONS IN PRODUCT DESIGN

Gerhard Reethof (Pennsylvania State University, Dept. of Mechanical Engineering, University Park, Pa.) *American Society of Mechanical Engineers, Design Engineering Conference and Show, Chicago, May 11–14, 1970; Paper* 11 p 12 refs

(A70-33520; ASME 70-DE-70) Avail: $1.00 members; $2.00 nonmembers

Reliability of a product in operational service is a design attribute similar to weight, performance, and, to some significant degree, cost. Manufacturing and quality control provide a product that meets the design intent. Since reliability is the product's probability of successfully completing its mission, probabilistic considerations, in relation to failure free operation, must be included in the design process. This paper introduces such probabilistic concepts, develops the necessary techniques and applies them to a typical design problem. Expected variations in the values of the load, the dimensions and the strength are considered with recognition of probabilistic strength degradation. Note is taken of the fact that the traditional factor of safety approach does not give proper recognition to the dispersion of the design variables. Author (IAA)

Review: This is a tutorial exposition on what is by now a very standard discussion of probabilistic considerations in the simple stress-strength model of failure. It appears in many places; if one has not seen it before, this is a good a place as any to look at it. If he has, there will be no need to look at the paper. A recent report [1] points out the difficulties in a practical application of probabilistic design of structures, namely, that the probability of having data sufficiently incorrect to cause failure is on the order of 10%. When this is taken into account the probability of success of any structure will not be greater than about 0.9 unless considerable testing is involved to eliminate some of the 10% of the cases.

Reference: Innes and Trent, D. J., "The unrealibility of structural reliability," ASM Technical Report No. P 9-12.4 (see review in this issue of RATR).

R70-15402 ASQC 824

A RE-DEFINITION OF ENDURANCE LIFE DESIGN STRENGTH CRITERIA BY STATISTICAL METHODS

Edward B. Haugen and John A. Hritz (Arizona University, Dept. of Aerospace and Mechanical Engineering, Tucson) *Air Force Conference on Fatigue and Fracture of Aircraft Structures and Materials, Miami, Fla., Dec. 15–18, 1969, Paper* 42 p 19 refs

Certain aspects of current combined stress fatigue theory and conventional criteria are examined from the extended visibility of recent hypotheses and experimental research. The deterministic model of combined stress fatigue strength is questioned, and a revised statistical model is proposed. A factual basis is established for defining the safe design criterion of a mechanical member (or system) subject to an alternating tensile stress superimposed on a mean stress, with the measure of reliability and fatigue life specified. Author

Review: This paper is on a worthwhile topic, and (presuming the authors' analysis is reasonable) the results will be helpful to designers and reliability engineers. The authors give much of their original data and technique of analysis, so that anyone who wishes can follow it rigorously and possibly suggest other ways of analysis. There is some difficulty with the statistical estimations used in the staircase method; this method was left out of an ASTM handbook on fatigue testing because the author of the method no longer wished to stand by his entire estimation procedure and another estimation procedure was not developed. The authors seem to go

off on a slight tangent for non-uniaxial stresses which they do not pursue further. Presumably their experiments were all uniaxial for stresses. The authors have made a contribution in emphasizing the probabilistic aspects of fatigue for combining the mean and alternating stresses, and their results will be of direct value to designers reliability engineers, and of course to those doing analytic work in fatigue.

R70-15407 ASQC 824

MINIMAL ENERGY DISSIPATION IN LOGIC

R. W. Keyes and R. Landauer (IBM Corp., Thomas J. Watson Research Center, Yorktown Heights, N. Y.) IBM *Journal of Research and Development*, vol. 14, no. 2 Mar. 1970 p 152–159 11 refs

A hypothetical device is used to construct a physically analyzable computing system. It is demonstrated that in this system the energy dissipations for the logic processes are larger than, but of the same order of magnitude as, minimal quantities based on thermodynamics and general phase considerations. It is also shown that any required reliability can be obtained with this device, without increased energy expenditure, but at the expense of an increasing time per computational step. Author

Review: This paper pursues a point raised earlier by one of the authors (R. Landauer, IBM J. Res. and Develop. *5*, 183 (1961)), namely, that general statistical mechanical considerations require a certain minimal energy dissipation in a logical operation. The present paper shows that the minimal energy dissipation can be closely approached, by analyzing a particular model logic device. Dissipation is associated with thermally induced fluctuations, and the paper also addresses the question: Do these fluctuations lead to an unavoidable limitation on reliability? It is argued that there is no fundamental limit on the reliability as long as one allows an unbounded amount of time for the logical process. Results such as these are interesting for those who are trying to understand basic physical processes and concepts, and they help to provide bounds beyond which it is known there is no point in trying to push a computer. The difficulty is that the analysis holds only for the particular model constructed, and it is not easy to get a completely general model. This paper is not for the ordinary design and reliability engineer but is directed toward those doing research.

R70-15411 ASQC 824; 831

Idaho Nuclear Corp., Idaho Falls.

ANALYSIS OF FAULT TREES BY KINETIC TREE THEORY

W. E. Vesely Oct. 1969 94 p refs

(Contract AT(10-1)-1230)

(N70-23045; IN-1330) Avail: CFSTI

A methodology is developed by which exact and detailed reliability information is obtained for any system fault tree. The system, called Kinetic Tree Theory, is believed to be a major advancement in the field of reliability analysis. The first assumption is that the components of the fault tree are independent; one component may occur at any number of places in the fault tree, but those components which are unique are assumed independent. The second assumption is that the minimal cut sets of the method are known. Fault trees of any structure and complexity are handled, and the expressions developed are in a simple form. Application to yield numerical results is straightforward. Author

Review: This is a mathematical paper and should have appeal to theoretically inclined reliability engineers. The author's major contribution is the formulation of kinetic tree theory, upon which a systematic method for reliability analysis is based. Much effort is devoted to the theoretical formulation of kinetic tree theory; however, the reader is provided with an appreciation of its practical application in Section II of the report. Here the author illustrates, through the use of a sample problem, the application of his reliability analysis procedure and discusses the nature of the reliability characteristics obtained. The proposed technique appears to have quite general applicability. The reader is expected to have a knowledge of basic fault tree concepts including some familiarity with minimal cut sets and maximal path sets.

R70-15412 ASQC 824

A RELIABILITY BOUND FOR SYSTEMS OF MAINTAINED, INTERDEPENDENT COMPONENTS

J. D. Esary and F. Proschan (Boeing Scientific Research Labs., Seattle, Wash.) *Journal of the American Statistical Association*, vol. 65, no. 329 Mar. 1970 p 329–338 13 refs

The minimal cut lower bound on the reliability of a coherent system, derived in Esary-Proschan for the case of independent components not subject to maintenance, is shown to hold under a variety of component maintenance policies and in several typical cases of component dependence. As an example, the lower bound is obtained for the reliability of a "two out of three" system in which each component has an exponential life length and an exponential repair time. The lower bound is compared numerically with the exact system reliability; for realistic combinations of failure rate, repair rate, and mission time, the discrepancy is quite small. Author

Review: This highly theoretical paper shows that a lower bound for reliability (obtained in a previous paper for statistically independent components) is also true for *associated* components. The concept of *association* is not too tractable, but the extension is a useful theoretical one. *Association* is a more general term than independence and includes it. The concept of *association* is not sufficiently easy that ordinary reliability engineers will be able to make use of the paper; however, those accustomed to reading theoretical statistics can probably interpret the paper for reliability engineers in special cases of interest.

R70-15422 ASQC 824

PREDICTION OF COMBINED DEPENDABILITIES

J. N. Siddall (McMaster University, Dept. of Mechanical Engineering, Hamilton, Ontario, Canada) *American Society of Mechanical Engineers, Winter Annual Meeting, Los Angeles, Nov. 16–20, 1969, Paper* 8 p 6 refs

(ASME-69-WA/Aut-18)

The first part of the paper explores the general use of basic probabilities in solving systematically high order probability prediction problems and gives digital computer subroutines. The second part of the paper extends the technique to the solution of combined dependability or reliability problems, in which the size can be extremely large; shows that the standard product solution for combined reliabilities is erroneous; and presents a proposed solution with simple formulae. Results given illustrate that the error increases as individual reliabilities are reduced. It can be significant even for high component reliabilities where large numbers of components are assembled. The product rule gives results that are too low. Author

Review: This is a two-part mathematical paper. The first part

discusses the calculation of various possible events and combinations thereof when a sufficient number (to determine the problem) of event-probabilities are given. (It should be noted that independence is not a property of probability but is a property of events.) On page 3, if two events are independent when conditioned on a third, they are not necessarily independent when conditioned on the complement of the third; therefore, independence under both must be established by the physical situation. (One must also remember that physical independence is not necessarily the same thing as statistical independence. Two quite unrelated things can have a common cause.) Basically, the first part of the paper deals with calculations involving formulae for the manipulation of probabilities. The ideas are contained in any elementary textbook on probability theory (e.g., *Probability: An Introductory Course* by Norman R. Draper and Willard E. Laurence, Markham Publishing Company, Chicago). The second part of the paper raises an apparent paradox which has bothered many reliability engineers. The concept under fire is that of reliability of a series system of components. The author asserts, by arguing the dependence of special events, that components in series do not behave as they do in isolation even though they may still be environmentally independent; hence the product rule for reliability is inappropriate. The fact of the matter is, the statistical dependence of the events the author is concerned with does *not* negate the validity of the product rule and hence the problem the author attempts to solve does not exist. The usefulness of his calculations then becomes questionable. On the whole, the paper offers no new results and will prove misleading to readers because of the errors it contains, particularly in the second part.

R70-15425 ASQC 824

A CLASS OF GENERAL RELIABILITY GROWTH PREDICTION MODELS

Donald R. Barr (Naval Postgraduate School, Monterey, Calif.) *Operations Research*, vol. 18, no. 1 Sponsored by Navy Jan. – Feb. 1970 p 52–65 6 refs

Reliability growth prediction models are discussed. Several factors are considered, such as the interdependencies of assignable cause failure modes, inclusion of an inherent failure mode, the repair policy, and the distribution of initial states of the system. Author

Review: This paper summarizes in a non-trivial way some of the work that has been done on reliability growth prediction models. It is limited to those which are modelable as Markov chains and presumes that the system reliability is never made worse by an attempted repair. This is a theoretical paper, and as such, is not of direct value to designers and reliability engineers but does, however, serve to consolidate the state-of-the-art in these models and expand it somewhat. Not all the mathematics was checked, but it appears to be quite competent.

R70-15426 ASQC 825; 872

MATHEMATICAL OPTIMIZATION TECHNIQUES FOR THE SIMULTANEOUS APPORTIONMENTS OF RELIABILITY AND MAINTAINABILITY

Anthony C. Shershin (South Florida University, Tampa) *Operations Research*, vol. 18, no. 1 Jan. – Feb. 1970 p 95-106 12 refs (A70-22211)

This paper sets forth mathematical means for optimizing the simultaneous apportionments of reliability and maintainability by means of two techniques: Lagrange multipliers and dynamic programming. Since one of the constraint equations involves allocating both variables, this simultaneous apportionment problem differs from the usual two-dimensional dynamic programming problems. Two cost problems are treated: the first minimizes cost while satisfying availability requirements under the assumption that an unlimited ceiling exists for the cost, and the second maximizes reliability and maintainability given a fixed budget. Although these problems appear closely related, step functions usually preclude considering them together. The paper also considers two numerical examples, an interesting cost model for maintainability, and using computers with its models. Author (IAA)

Review: This paper treats an important topic, but it is so terse that those who are not otherwise familiar with the field will find the paper tough-sledding indeed (a style commonly used in this journal). The author's approach is reasonable; in fact, it is quite straightforward. The solutions are indicated rather than dealt with in detail; that is, one not already expert in the field would not be able to solve the problems with the information which is given. These kinds of analyses are generally done with guessed-at data and are useful mainly to show trends and to "design the ball park in which the game will be played." Therefore, it is quite useful to know the width of the minima (as the author has suggested in referring to sensitivity analyses). Very often the final apportionment within the general minimum regions will be governed by factors which are not accounted for in the model.

83 DESIGN

R70-15379 ASQC 831

Northwestern Technological Inst., Evanston, Ill.

SELF-DISGNOSIS AND SELF-REPAIR IN MEMORY: AN INTEGRATED SYSTEM APPROACH

S. A. Szygenda (Missouri Univ., Rolla) and M. J. Flynn [1969] 82 p refs Sponsored in Part by AEC

Self-repair techniques are developed for a computer memory. These techniques: 1) detect and correct single solid faults and mask multiple failures caused by these faults; 2) use hardware methods for checking, wherever possible; 3) detect faults without a performance penalty; and 4) minimize redundant hardware. Author

Review: Computer designers will be especially interested in this report, as it presents some very practical design concepts for including self-diagnosis and repair capabilities. Even though the concepts were not checked in detail, they appear to be technically sound. It is difficult in places to follow the line of reasoning, mainly because of the organization of the report. For example, the reader must do some analyses on his own to verify that all failure modes are considered (since they are not clearly itemized for all parts of the system). The approach of using a variety of self–diagnosis and repair techniques is much more realistic for achieving a workable design than relying on one technique, as many papers in this field have done. It is indeed significant that all of the techniques used in this design approach can be implemented with designed-in hardware rather than having to

rely on self-checking software which requires additional computing time. The approach also appears to contain adequate provision for "checking the checkers," a facet of practical design which many other proposed approaches have overlooked. The report does not recognize whether computer hardware using these concepts has been built and tested; however, it is apparent that the concepts are based on in-depth knowledge and experience with computer circuitry. In summary, the report will be very worthwhile reading for designers and reliability engineers who are concerned with providing self diagnosis and repair in computer design.

R70-15381 ASQC 830
Air Force Systems Command, Wright-Patterson AFB, Ohio. Foreign Technology Div.
METHODS OF IMPROVING THE OPERATIONAL RELIABILITY OF CONTROL COMPUTERS
N. I. Tsiklinskii et al 22 Sep. 1969 37 p refs Transl. into ENGLISH from Avtom. Upravlenic i Vychisl. Tekh. (Moscow), no. 7, 1967 p 206–235
(N70-30318; AD-701991; FTD-HT-23-230-69 (JPRS))
Avail: CFSTI

Functional checking is a method for enhancing the operational reliability of digital computers. For control computers, the reliability is the capability of the computer to solve problems with a specified accuracy and in a specified time; any deviation from this performance is considered a failure. Two groups - program and hardware - of checkout methods have been known; these groups are subdivided into individual methods. Of these, the operational active check, i.e., the automatic check during computer operation which precludes using incorrect solution, is the most important for control computers. Characteristics of computer checks and their influence on reliability are given. TAB

Review: This paper was originally published in Russian in 1967 and translated into English in 1969. The method of improving the reliability of control computers which is given the most prominence is monitoring of the functions and replacement of bad elements by redundant ones. Simple mathematical models are hypothesized for various processes and the results analyzed. There is little in the paper that is new in this country at this time, but the paper is a reasonable exposition on the topic. It does not deal with internal checks and corrections such as those made possible by more complicated coding. It is not always clear how the malfunctions are actually detected by the monitor since, in order to know that an error occurs, one needs to know the correct answer; and in order to have the correct answer available, one needs either to use a pre-arranged checking routine where the answers can be stored or to use a redundant section of the computer and compare the answers. Presumably it is the former that is meant in this paper. Those design and reliability engineers who are responsible for control computers might care to look over this paper in case there is something in it with which they are not familiar.

R70-15385 ASQC 837; 824
OPTIMIZATION OF STRUCTURES WITH RELIABILITY CONSTRAINTS
F. Moses (Case Western Reserve University, Cleveland, Ohio) *International Symposium on Structural Optimization, Istanbul, Oct. 6–8, 1969, Paper* 26 p 36 refs
(Grants NSF GK-74; NSF GK-1871)

The work surveys minimum weight design of structures using reliability or failure probability as the design constraint. Examples are illustrated from civil engineering structures as well as aircraft, heat shields and other aerospace problems. Some background material is given on computing failure probability from the frequency distributions of applied loads and strengths. Specific reliability based optima for multi-member systems are shown for weakest-link structures which fail if any element fails and redundant structures (fail-safe) designed for ultimate load conditions. The sensitivity of optimum design to reliability level as well as parameters in the reliability analysis is discussed. Mathematical programming methods suitable for reliability based optimization are presented. Author

Review: This paper will be of value primarily to those who have some previous familiarity with probabilistic design of structures. It is a survey paper, as indicated in the summary; the examples are general ones rather than specifically detailed, worked out calculations. While the subjects mentioned in the summary are touched upon in the paper, it is easy to infer that they are treated in greater depth than is actually the case. The discussions themselves are good; they seem to be fair, and they are well referenced. As the author mentions, not all probabilistic analyses of structures have used suitable models, viz., statistical independence is such a tractable assumption that people are tempted to use it even in places where it is not at all suitable. The language of the presentation is difficult to apply to fatigue, stress corrosion, or other failure modes that do not easily fit the simple stress-strength model for failure. The analysis of costs in equation 14 does not allow, for example, for the time value of money (or some equivalent). One of the biggest drawbacks to the use of probabilistic design in structures is that the probabilistic data are just not available in sufficient quantity or quality for most structural materials. Some discussions of this have been given in analyses of MIL Handbook 5 by members of Battelle Memorial Institute. A good probabilistic analysis of structures requires that accurate knowledge, be available at very low probabilities in the strength and load curves—this is exactly where it is most difficult to get good data. Furthermore, it is difficult to know whether the materials one receives as a result of a purchase order are in fact representative of the population from which he does have some data. In view of these difficulties, the mathematical theory for probabilistic design of structures is in much better shape than the application of the theory in practice.

R70-15389 ASQC 837; 824
A METHOD OF RELATING FACTOR OF SAFETY AND RELIABILITY
C. Mischke (Iowa State University, Dept. of Mechanical Engineering, Ames) *American Society of Mechanical Engineers, Winter Annual Meeting, Los Angeles, Nov. 16–20, 1969, Paper* 5 p
(ASME 69-WA/DE-6)

A formal relationship between factor safety and reliability is presented. Inasmuch as most engineering application will not economically justify the necessary experimental work to successfully implement the formal approach, a method for making conservative decisions based upon Bienayme-Chebyshev and Camp-Meidell theorems is offered. This step-by-step procedure reminds the engineer of the influence of each piece of information relating to strength and loading upon his factor of safety decision. The potential gain (reduction of weight, cost, etc.) can be compared to the cost of the experimental program necessary to establish modality, skewness, or symmetry. Author

Review: This is a short mathematical paper which uses the Chebyshev and related inequalities to set lower bounds on the re-

liability when only the mean and standard deviation of the stresses and strengths are known. It presumes the simple stress-strength model for failure. The derivation of the Chebyshev inequalities presumes that the mean and standard deviation are known exactly, not estimated from the data. Standard deviations are notoriously difficult to calculate accurately because the sampling spread is so much greater than that for the mean; therefore, in using the Chebyshev inequalities, one should always take an upper bound to the standard deviation. Somewhat more restrictive bounds can be taken in any particular situation if everything that is known about the distribution is included in the derivation of a Chebyshev-type inequality; for example, the strict Chebyshev inequality presumes that half of the distribution is concentrated at one standard deviation below the mean and the other half concentrated one standard deviation above the mean. The derivation for the uni-modal one presumes a uniform distribution over the appropriate range. The author's presumption that the mean of a product is the product of the means is not in general correct. He should have waited until making the linear assumption before writing an equation for the mean. The derivation also implicitly presumes that there is no correlation whatsoever between the stress and the strength.

R70-15397 ASQC 837

COMPUTER-AIDED DESIGN AND WORST-CASE ANALYSIS OF MAGNET WIRE COILS

R. E. Wolf and D. A. Janninck (Automatic Electric Labs, Northlake, Ill.) *Oklahoma State University and the National Association of Relay Manufacturers, Annual National Relay Conference, 18th, Oklahoma State University, Stillwater, Okla., Apr. 28–29, 1970 Proceedings* Scottsdale, Ariz. National Association of Relay Manufacturers 1970 p 1-1 to 1-24

Avail: $5.00

A set of acceptable guidelines is presented for the selection of magnet wire coils for existing electromechanical devices and for the design of new coils for new devices. A computer program is described which aids in coil design process and worst-case analysis. P.R.F.

Review: Electromechanical relays are apt to be regarded as much less reliable than semiconductors these days, largely perhaps because many electrical angineers are much more familiar with semiconductors than they are with low-level relays. This paper attempts to cure that problem by showing how the relay coil can be analyzed in terms of its various kinds of performance. The worst-case analysis is shown (as opposed to a statistical kind), and has the advantages that it is simpler and is probably more likely to give good results. Any analysis which tries to pin certain kinds of things down too closely is doomed to failure because there is just not enough known for such a detailed analysis to be valid. For example, in the structural reliability field, it has recently been suggested that one should take the reliability calculated in the often-touted fashion and multiply it by 0.9 (the probability that the data are good). The remaining contribution to the probability expression is zero since it relates to the probability that the data are so poor that the structure so designed will fail for sure. A worst-case analysis avoids the heavy dependence on detailed statisticaly data and the authors were wise to choose it. While life is not mentioned explicitly here, it obviously can come in implicitly by ensuring that the device will operate over wide variations of the parameters. Preferably(ideally?) the electrical design engineer should leave relay design up to relay companies, but at a minimum he needs to know how to write intelligent specifications. This article will help him do that.

R70-15399 ASQC 830

PHASE LOSS DETECTION: RELIABLE OR ROMANTIC?

E. U. Thomas (Grumman Aerospace Corp., Bethpage, N. Y.) *In: Oklahoma State University and the National Association of Relay Manufacturers, Annual National Relay Conference, 18th, Oklahoma State University, Stillwater, Okla., Apr. 28–29, 1970 Proceedings* Scottsdale, Ariz. National Association of Relay Manufacturers 1970 p 22-1 to 22-9 2 refs

(A70-29349) Avail: $5.00

Discussion of the pitfalls inherent in the indiscriminate use of voltage sensors in industry. Voltage sensors frequently fail to detect the loss of the supply phase voltage, and their very presence in a circuit often gives rise to a false sense of security. Situations and conditions under which the 'axiomatic' choice of a voltage sensor may not be the wisest one are described and discussed along with alternative approaches to some of the problems. IAA

Review: This author is well known, for both his active interest in promoting the use of relays and his never-ending discouraging of the improper use thereof. This paper maintains the high standard he has previously set in that it gives in very detailed fashion the pitfalls of design into which many designers descend time after time. One of the big techniques for high reliability is to "merely" do as well as we now know how. This paper is a big step in that direction for one particular application of relays. Designers and reliability engineers alike should at the very least know that this paper exists and where to find it when they are concerned with a relay application for overvoltage. This kind of paper is an excellent aid for increasing aerospace (and other) reliability.

R70-15400 ASQC 830; 873

REPAIRABILITY AS AN ELEMENT IN DESIGNING FOR RELIABILITY

T. A. Daly (Westinghouse Electric Corp., Headquarters Engineering, Pittsburgh, Pa.) *American Society of Mechanical Engineers, Design Engineering Conference and Show, Chicago, May 11–14, 1970, Paper* 7 p 6 refs

(ASME 70-DE-38) Avail: $1.00 members; $2.00 nonmembers

Factors to be considered in product design and development, plus a number of actions by design management which will contribute toward improving the repairability of the end product, are recommended. Author

Review: The topic to this paper is an important one, and the author has shown many ways in which improving the ease of repair can improve the reliability of a product, especially when the product is being used after the repair. He makes his points largely by example, and these are graphic enough to reinforce the need for considering repairability. The paper does not consider the other problem associated with making repairs easy. This other problem can best be illustrated by the use of sockets for transistors vs. soldering them directly in the circuit; one is easier to repair but undoubtedly less reliable and vice versa. Naturally, one should do all he can to make repairs easy within cost and packaging constraints—when there is no particular life tradeoff against or reliability. But when tradeoffs have to be made, such that costs increase or life decreases, then a higher-level figure-of-merit is needed in order to evaluate the best amount of the tradeoff.

R70-15408 ASQC 838

RELIABLE POWER FOR HANFORD

J. H. Budd (ITT Federal Support Services, Inc., Electric Utility Sec-

tion, Richland, Wash.) *Power Engineering,* vol. 74 Mar. 1970 p 49–52

The Atomic Energy Commission's plutonium-producing plant is discussed. Multiple supply lines, high-speed relaying and automatic closing, and detailed operating procedures provide a highly reliable power supply. Prevention maintenance, involving both destructive and nondestructive tests, is described. P.R.F.

Review: This is a summary of the procedures and precepts that have been followed to produce reliable electric power for the Hanford plutonium plant. Redundancy (with as much statistical independence of failures as possible), preventive maintenance on a realistic scale, and attention to the many details of the condition of the equipment are the main routes for achieving this high reliability. The paper is worthwhile reading for those who are concerned with power supplies whose interruption causes severe trauma. The ideas and methods are good. No mention is made of the extra costs involved in providing this reliable power as opposed to the usual reliability provided by a power company.

R70-15409 ASQC 830
DESIGN FOR DAMAGE TOLERANCE
Richard C. Combes, Jr. (Lockheed-Georgia Co., Marietta, Ga.) *(American Institute of Aeronautics and Astronautics and American Helicopter Society, VTOL Research, Design, and Operations Meeting, Georgia Institute of Technology, Atlanta, Feb. 17–19, 1969.) Journal of Aircraft,* vol. 7, no. 1 Jan. – Feb. 1968 p 18–20 2 refs (A70-20401; AIAA Paper 69-212)

The emergence of damage tolerance as a primary design consideration for new generations of aircraft is shown to be the result of concern for increased safety and reliability by airframe manufacturers and regulatory bodies. Design criteria applicable to the case of structurally damaged components are defined. Application of the "failed single principal member" concept to typical airframe construction is found to have little effect on aeroelastic properties. Internal load paths for a damaged structure are described, with typical examples of design practices aimed at minimizing structural vulnerability to damage. Author (IAA)

Review: The failsafe concept of aircraft design has been known for some time so it is not entirely clear what the purpose of this paper is. The paper does give some examples of failsafe design (the author calls it damage tolerance). Perhaps most significantly, he states that one need not make a tradeoff between failsafe and safe-life design but that both can be accomplished at the same time with negligible penalty. If this is his message, it is relatively new, since most authors have contrasted the two and suggested that often one has to choose between them in view of the many constraints on the design. The examples the author gives of failsafe design are clear. For those who are not familiar with the principle, this paper offers a good introduction to it.

R70-15429 ASQC 837; 824
RELIABILITY-BASED STRUCTURAL DESIGN
Fred Moses (Case Western Reserve University, Cleveland, Ohio) and John D. Stevenson (Westinghouse Electric Corp., Nuclear Engineering Systems Div., Pittsburgh, Pa.) *Journal of the Structural Division,* vol. 96, ST 2 Feb. 1970 p 221–244 21 refs (Grants NSF GK-74; NSF GK-1871)

Methods for incorporating reliability analysis into optimum design procedures are presented. Examples are given for multimember elastic truss design and frames designed according to limit-design theory. The approach adopted is to design for a specified probability of failure, in which the failure probability is evaluated from a sequence of numerical integrations. The subject of sensitivity of statistical parameters is considered, with the presentation of results for the reliability-based design of rigid frames, using different frequency distributions and parameters. Author

Review: This is a good paper in that it presents well the philosophy and some of the applications of probabilistic criteria for design of structures. The authors point out where statistical independence between failures of elements may be assumed and where it cannot. This fact has sometimes been overlooked. The biggest problem in applying probabilistic design to structures in a real engineering context as opposed to a research context is that sufficient data are rarely available for meaningful results to be obtained; see, for example, the papers by Rowe and by Bouton and Trent which are reviewed in this issue of RATR. Most analyses presume the existence of tractable unimodal distributions. The existence of defective material, i.e., bimodal distributions having the second mode away out on the tails, could appreciably change the design. Extrapolation from handbook values will often be quite unsatisfactory. Research in this field is justified, and this paper does justice to its subject.

R70-15430 ASQC 837; 824
CURRENT EUROPEAN VIEWS ON STRUCTURAL SAFETY
Roy E. Rowe (Cement and Concrete Assoc., Wexham Springs, England) *Journal of the Structural Division,* vol. 96, ST 3 Mar. 1970 p 461–467 2 refs

The current thinking of committees in Europe which have been considering the problems of structural safety and the formulation of design recommendations covering safety aspects is presented. In addition, the fields in which further study is required to improve the treatment of structural safety are indicated. It is concluded that the limit state method offers both a reasonable and a practical approach which has the capability of incorporating the developments of the strict probabilistic or reliability approaches. Author

Review: This is a very interesting report, especially in view of the amount of consideration given to the probabilistic calculation of reliability vs. factor of safety. The conclusion was that at the present state-of-the-art, judiciously chosen factors of safety (undoubtedly derived from recent experience) are much more feasible than the probabilistic approach. This is due largely to the lack of data for the probabilistic approach. In view of the many articles being written in the reliability literature on the probabilistic approach to the strength of structures, these conclusions are of interest. The recent paper by Innes Bouton and D. J. Trent which is reviewed in this issue of RATR bears out the advisability of this European conclusion: the probabilistic approach to the design of structures is great, but there are just not enough data to design most structures sensibly that way.

R70-15433 ASQC 835; 782; 844
THERMAL DESIGN CONSIDERATIONS FOR ELECTRONIC COMPONENTS
E. P. Black and E. M. Daley (General Electric Co., Reentry and Environmental Systems Div., Philadelphia, Pa.) *American Society of Mechanical Engineers, Design Engineering Conference and Show, Chicago, May 11–14, 1970, Paper* 5 p 7 refs

(A70-33422; ASME-70-DE-17) Avail: $1.00 members; $2.00 nonmembers

The purpose of this paper is to provide a plan for the design engineer in the thermal design approach for packaging electronic components. Included in the plan are the temperature characteristics of components, a description of failure rate, types of failures, the reliability aspects of components in relation to temperature and a method for selecting components. Other considerations in the design approach include various manufacturing processes such as soldering, molding and exothermic reactions of plastics which can subject components to high temperatures. Author (IAA)

Review: This is an excellent title for an intriguing subject. However, the paper does not live up to the expectations generated by the title and topic. One of the basic objections to this paper is that it is poorly written and appears to be incomplete. The mathematical model and Figure 1 for an integrated circuit are exact duplicates of pages 413, 416 of RADC Reliability Notebook TR 67-108. What has been added to the Reliability literature on this subject? Figure 4 shows the comparison of diode junction temperatures for various fabrication techniques, and lists dip soldering, hand soldering, and welding. The paper discusses wave soldering as having the "most severe" effect on junction temperature. The Figure does not support these statements nor does experience indicate that "hand soldering" is less severe than automatically-controlled wave soldering. It would have been valuable to read how hand soldering is controlled and the degree of uniformity in the control. It would also be valuable to define "dip soldering" in terms of hand-held, machine-held, dwell time (since you cannot see the joint, some predetermined method of removal is needed), fluxes used (they should not be the same) for each system. The paper does present a summary of the steps needed to consider thermal effects on electronic components, but the material should be edited prior to being distributed to newcomers to the field. This paper as presented is not recommended for further reading.

R70-15435 ASQC 830; 844

DESIGN FOR LIABILITY PREVENTION

T. A. Daly (Westinghouse Electric Corp., Reliability and Product Safety, Pittsburgh, Pa.) *In: Proceedings of the 1970 Product Liability Prevention Conference, Newark, N. J., Aug. 26–28, 1970* Sponsored by American Society for Quality Control, American Society of Safety Engineers, Institute of Electrical and Electronic Engineers, and Newark College of Engineering American Society for Quality Control, Inc. 1970 p 27–38 5 refs

The point is made that product liability prevention should receive overt attention in the design and development phase. It is recommended that complete design specification, formal desgin review, failure mode analysis, reliability estimation, and other techniques be used to carry out a defensive designing program. An existing reliability program is seen as a natural vehicle for liability prevention efforts. P.R.F.

Review: The intent of this paper was to present to non-engineers various tools that are available to prevent liability or—in the reliability field—prevent failures. It is a good general paper and satisfies the intent of the presentation. It outlines the techniques used in designing reliable products which should have a low probability of liability exposure. Parts of the corporate program have also been presented before, e.g., in the papers covered by R65-11959, R67-13192, and R67-13376, and in a paper "Minimizing hazards in design," presented to the AMA in April 1970. One chart shows Liability Loss Experience up until 1966; data since then are not presented (apparently they are not yet available due to the slowness of court cases). This paper is recommended for Engineering and Insurance Company Senior Executives.

84 METHODS OF RELIABILITY ANALYSIS

R70-15380 ASQC 844

Air Force Systems Command, Wright-Patterson AFB, Ohio. Foreign Technology Div.

FATIGUE AND EMBRITTLEMENT OF METALLIC MATERIALS

V. S. Ivanova et al 23 Sep. 1969 154 p refs Transl. into ENGLISH from the Russian

(N70-18239; AD-696519; FTD-HT-23-258-69(JPRS))

Avail: CFSTI

The subjects covered include: methods of determining metal susceptbility to brittle fracture and the pattern of crack propagation under static and cyclic loads, the embrittling effect of cyclic loads, the influence of stress concentrators and fretting-corrosion on fatigue resistance, problems of developing materials with high resistance to crack propagation, and various aspects of elastic meterials and their mechanical properties. TAB

Review: This book is a reasonably up-to-date discussion of its title. It was originally published in 1948 in Russian and translated into English in 1969. Metallurgical research in Russia is probably as good as or better than that in this country; so the book is authoritative. (They experience much more difficulty in applying their research than in the U.S. since they have a tremendous shortage of engineers.) The content of the book is well described by the chapter headings: 1 - Dislocation Energy Analysis of Deformation and Fracture of Metals 2 - Work Hardening of Metals and Alloys as a Result of Trapping of Dislocation and Other Defects 3 - Methods of Determining the Disposition to Brittle Fracture by the Resistance to Crack Propagation 4 - Laws of Crack Development and Resistance to Crack Propagation Under Cyclic Loads 5 - Age Embrittlement of Metal 6 - The Effect of Stress Concentration in Metallurgical Factors on Cyclic Strengths of Steel 7 - Cyclic Strength Under Fretting Corrosion Conditions 8 - Fiber Reinforced Metal Materials. The bibliography contains over 400 items. Much of the discussion of the book is concerned with crack propagation (fracture mechanics). This phenomenon is also considered in this country to be the main key to materials failure. The main value of this good inexpensive text will be to those who are interested in a theoretical treatment of the subject. Utility to designers and reliability engineers is small because they probably do not have the background to understand it without extensive and intensive study. Unfortunately, the material is printed half-size and the reproduction is often poor, both of which make it extremely difficult physically to read. The translation is remarkably good and little difficulty is experienced from that point of view.

R70-15382 ASQC 844; 775

Tyco Labs., Inc., Waltham, Mass.

STUDY OF THE GENERAL MECHANISM OF STRESS CORROSION OF ALUMINUM ALLOYS AND DEVELOPMENT OF TECHNIQUES FOR ITS DETECTION Final Report, 1 Jun. 1966 – 1 Jun. 1969

S. B. Brummer, R. O. Bell, F. H. Cocks, and A. Cordellos Sep. 1969 336 p refs

(Contract NAS8-20297)

(N70-14558; NASA-CR-102409) Avail: CFSTI

The objectives of this investigation were to examine the mechanism of the stress corrosion cracking (SCC) of Al alloys (phase 1), and to study the feasibility of using instrumental methods to detect stress corrosion cracking on fabricated Al alloy parts (phase II). The mechanism of SCC of high strength Al alloys was investigated using electrochemical, mechanical, and electron microscopic techniques. Corrosion and stress corrosion experiments were carried out in 1M NaCl buffered to pH 4.7, usually at 30 C, using the commercial alloys 7075 and 2219 and also relevant pure materials. Correlations were made between susceptibility to SCC and the following properties of the particular alloys: metallurgical condition, mechanical properties (macroscopic and local), corrodibility (macroscopic and local), ambient conditions in the corrodent, and surface treatment. Author

Review: This is a very comprehensive report which covers a three-year research program. It is directed mainly toward metallurgists and other specialists involved in this field rather than design and reliability engineers. There is a great amount of detail on the ultrasonic techniques which can be helpful to others doing research in the field. The report discusses many of the experimental difficulties and dead ends as well as the successes. (This certainly gives one more confidence in the results.) Stress corrosion is an important failure mechanism in aerospace structures, especially with many of the newer "higher strength" alloys. These tend to be developed primarily for high tensile strength and often suffer from poor resistance to other failure mechanisms. This report helps to generate a greater amount of understanding of why and how stress corrosion proceeds; it helps to make the important distinction between plain corrosion and stress corrosion, and its discussions of the experimental techniques are in themselves good contributions. (In some of the figures, the points are very widely scattered. There is no measure of uncertainty in the location of the lines, and it is not clear that the line is at all unique. Examples of this are Figures 32, 36, and 136.)

R70-15383 ASQC 844; 833

Deutsch Relay Div., East Northport, N. Y.

STUDY OF THE PARAMETERS AFFECTING CONTACT PERFORMANCE OF HIGH RELIABILITY RELAYS

Charles P. Nunn and S. Bradford Mc Rickard Sep. 1969 68 p refs

(Contract NAS12-634)

(N70-17300; NASA-CR-86321) Avail: CFSTI

The process, contamination, and contract material parameters that are known to affect the electrical contact performance of high reliability, crystal-can type relays were studied. The study was built around the sealed switching module contract system which, by virtue of its design, eliminated the gross effects of the coil assembly from the contacts, thereby providing an organic free contact module. A fundamental failure mechanism was found on the gold plated, silver substrate contact system when operated under extremely dry conditions. Cold welding of the contacts would occur after 30,000 operations due to mechanical wear through the gold plate and exposure of the soft silver-palladium alloy substrate material. This basic material failure mode was eliminated by the introduction of a 2-5 micron, electroplated rhodium contact system. Author

Review: The title of this report is quite descriptive of its contents. The report will be of value to reliability engineers (especially those concerned with failure modes and effects), failure analysts, and relay engineers. The development of an alloy which can be used for both the contact and the spring (a monolithic contact) seems quite worthwhile in that it eliminates some manufacturing steps and some potential failure mechanisms. The report appears to be reasonably complete although there were probably other setbacks during the course of the investigation that it was felt not worthwhile mentioning. Not all problems were completely solved as of the end of the report (although they are defined), for example, the water vapor vs. cold welding problem.

R70-15386 ASQC 844

Boeing Co., Renton, Wash. Commercial Airplane Div.

THE INFLUENCE OF WELD DEFECTS AND REPAIR WELDS ON PERFORMANCE

D. V. Lindh 5 Sep. 1969 68 p refs

(N70-18537; AD-697243; D6-24409) Avail: CFSTI

The evaluation of a semi-empirical method for predicting the influence of weld defects on properties is described. Weld defects are shown to be very harmful to the fatigue properties of a weldment. The effect of weld repairs on properties are discussed, and the possibility of introducing severe defects during repair welding considered. Author (TAB)

Review: This good paper attacks another one of the engineering problems in reliability, namely, whether certain kinds of repairs do more harm than good. In this case, the original welds may not be perfect and one tries to repair the weld by welding parts of it again. The approach appears to be a good engineering attack on the problem; while undoubtedly one could argue that this or that would have been better, it does not seem that such quibbling would change the basic results. Unless the original defects in the weld are very bad, trying to weld it again will only make matters worse. There are many such engineering problems to be analyzed in the construction of aerospace equipment. Many of the questions have not yet even been asked in serious fashion. It is good to see time and effort being well spent on this very important topic.

R70-15390 ASQC 844

THE UNRELIABILITY OF STRUCTURAL RELIABILITY

Innes Bouton and D. J. Trent (North American Rockwell Corp., Space Div., Downey, Calif.) *American Society for Metals, Materials Engineering Congress and Exposition, Philadelphia, Oct. 13–16, 1969, Paper* 10 p 3 refs

(P 9-12.4) Avail: $1.50 members; $3.00 nonmembers

The principles of structural reliability are discussed. Instead of considering that the strength distribution corresponds precisely to the analytically determined value, an error function is introduced representing the accuracy of typical analyses. Available data on this error function indicate that the actual strength of almost one in ten structures is less than two-thirds of the value predicted analytically. The concept of strength scatter is discussed and it is concluded that attention should be given to low strength scatter as a desirable physical property of metals and other materials. Strength testing is seen as a potent tool for disclosing errors and for upgrading true structural reliability. P.R.F.

Review: Hurray for this paper! These authors are well known

for their papers having a practical approach to structural reliability, and this paper is one which everyone should read who is writing papers on probabilistic design of structures. Everyone who reads those papers should also read this one. The message should be given in the trade magazines as well as at technical conferences. Too many engineers (and theoreticians) are entranced by the very high precision with which reliability calculations can be made on paper or on a computer. The fact that their conceptual model is usually quite incomplete or inaccurate does not seem to bother them. The message of this paper should be hammered home again and again by everyone who has the chance, especially since there are many self-appointed missionaries running around or preaching the gospel of simple-minded probabilistic design of structures. Neither the authors nor this reviewer object to probabilistic-design; they like it and are encouraging a realistic approach to the method rather than the ubiquitous ivory-tower dilletantism.

R70-15392 ASQC 844
LOCAL STRESS-STRAIN APPROACH TO FATIGUE ANALYSIS AND DESIGN
T. H. Topper and C. V. Byre Gowda (Waterloo University, Waterloo, Ontario, Canada.) *American Society of Mechanical Engineers, Design Engineering Conference and Show, Chicago, May 11–14, 1970, Paper* 11 p 32 refs
(Grants DRB-G-9535-49; NRC-A-1694)
(A70-33424; ASME 70-DE-24) Avail: $1.00 members; $2.00 nonmembers

Fatigue failure differs from other structural failure modes in that it initiates by a highly localized mechanism rather than a large-scale deformation process and generally requires a larger number of load applications. Designers assessing resistance to fatigue failure in structural parts must also consider an added complication in that the usual initiation sites of fatigue cracks are in a small region at a stress raiser such as a notch, fillet or bolt hole. Recent investigations have shown that local inelastic deformation at stress raisers is common even in components in which the largest loads cause nominal stresses well below yielding. Consequently, conventional linear elastic stress analysis is inadequate to assess either the stress-strain response or residual stresses resulting from inelastic deformation at the critical location. Both are critical in obtaining an accurate assessment of fatigue life. This paper describes recent progress in understanding the local stress-strain behavior at stress raisers and inelastic material stress-strain response. Emphasis is placed on the utilization of these developments in designing engineering structures to function reliably in a service environment including variable amplitude loading. Author (IAA)

Review: This is a state-of-the-art survey of pratical means of performing a stress-strain analysis for fatigue. The authors point out that some of the theoretical developments are not yet suitable for application by designers and fatigue analysts in practical problems. They discuss each of the areas associated with predicting fatigue life and point out how and where development must proceed in the theory. It is a good review; it does not use so much jargon that it is not understandable by the ordinary mechanical design engineer, and it is related to the design engineer's practical problems. The reliability of aerospace (as well as most other) structures is often determined by fatigue considerations; therefore, an understanding of the practical aspects of fatigue is required of designers and reliability engineers.

R70-15393 ASQC 844; 775
ESTABLISHING THE FAILURE PATTERN BASE THROUGH SIGNATURE ANALYSIS
H. G. Tobin (IIT Research Institute, Chicago, Ill.) *American Society of Mechanical Engineers, Design Engineering Conference and Show, Chicago, May 11–14, 1970, Paper* 9 p 5 refs USAF supported research
(A70-33505; ASME 70-DE-34) Avail: $1.00 members; $2.00 nonmembers

Discussion of some of the more common failure modes of mechanical and electromechanical components, and various sensing techniques which are available and may be useful in signature analysis. To assist the designer of mechanical systems in predicting what their likely failures may be, examples of various sensing techniques, and monitoring of the primary failure modes to determine the condition of the systems are presented. IAA

Review: Unfortunately, this paper omits a good definition of signature analysis, and the term to the uninitiated is quite baffling. Signature analysis looks at the behavior of a part in response to stimuli which may be internal as well as external. The response is called a signature, an analogy to the signature of an individual, since the signatures are felt to be representative of the condition of the item and often they are highly personal; that is, nominally alike devices have only nominally alike signatures—there are differences which can be observed. This is a state-of-the-art paper; it does its job reasonably well in showing a reliability engineer the kinds of things he should look for and the kinds of signatures that can be detected. Unfortunately, the list of references is rather small for those who want further information. Thus, the paper will be more suitable for managers and others who wish a not-too-technical, not-too-deep introduction to the subject.

R70-15395 ASQC 844; 775
USE OF SECONDARY EFFECT SIGNATURES TO DETECT POTENTIAL FAILURES
J. E. Bridges (IIT Research Institute, Chicago, Ill.) *American Society of Mechanical Engineers, Design Engineering Conference and Show, Chicago, May 11–14, 1970, Paper* 11 p 13 refs USAF supported research
(A70-33517; ASME 70-DE-58) Avail: $1.00 members; $2.00 nonmembers

Description of the application of secondary effect signatures i.e., phenomena generally not associated with the primary purpose of a component or system - to determine the status of equipment. To assist the designer, secondary effect signatures are classified in terms of communication paths and are electromagnetic, mechanical, or chemical in nature. As a design approach illustration, the application of secondary effect signatures to detect certain precursors of a potential failure of jet aircraft engine compressor blades is presented. IAA

Review: This paper treats a topic very similar to that in the paper, "Establishing the failure pattern base through signature analysis," by H. G. Tobin which is also reviewed in this issue of RATR (the authors are associated with the same institution), but deals explicitly with secondary effect phenomena rather than the primary ones. It is a good paper for this purpose; it keeps the amount of jargon to a minimum so that maintenance and reliability engineers can understand it. It is largely directed toward aerospace reliability, but the principles and state-of-the-art which are explained are suitable almost anywhere. A great deal of emphasis in the reliability field is being placed on sensing an about-to-fail device and repairing it before the failure can do considerable system damage, preferably during scheduled maintenance. This paper explains some of the state-of-the-art of those procedures.

R70-15401 ASQC 844

THE EVALUATION OF FLEXURAL PIVOTS TO MEET CRITICAL PERFORMANCE AND LIFE REQUIREMENTS

J. L. Olson (Hughes Aircraft Co., Research and Development Div., Culver City, Calif.) *American Society of Mechanical Engineers, Design Engineering Conference and Show, Chicago, May 11–14, 1970, Paper* 8 p 4 refs

(A70-33522; ASME 10-DE-76) Avail: $1.00 members; $2.00 nonmembers

Description of the evaluation work being done to establish confidence in miniature versions of commercially available, self-contained flexure pivots. Following a detailed description of the test program, test results and conclusions are presented to enable other potential users to accurately assess the use of these pivots in their applications. In addition, background information is presented on the principles of operation, previous utilization, and pros and cons of the use of flexural pivots in critical mechanisms. IAA

Review: This paper is an illustration of the attention to detail which high reliability requires. In this instance, flexural pivots have to be tested in order to find their life properties. The manufacturer's data give only one value for life (when no probabilities are specified, one ordinarily presumes the life to be a median life). The experimental fatigue data show the extreme spread that can be obtained in life during fatigue tests and some of the difficulties involved with creating a highly reliable testing machine (since the machine, itself should be much more reliable than the items which it tests). No mention is made of the effect of environment on fatigue life. All of these tests were presumably run in normal air; some experimentalists have found a difference in fatigue life between vacuum and ordinary air. The author notes that the lives at constant stress did not have a normal distribution. Most observers use a lognormal or Weibull distribution for life at a constant stress.

R70-15403 ASQC 844

Cambridge Univ. (England). Dept. of Engineering.

HIGH-STRAIN, LOW-ENDURANCE FATIGUE: A REVIEW

K. J. Miller 1969 121 p refs

(N70-18011; CUED/C-Mat/TRI) Avail: CFSTI

Reviewed are the basic aspects of deformation and fatigue studies with emphasis on the most important parameter of straining rate. It is shown that prior cycling action can modify both static and conventional creep test behavior as well as the structure of the material. Since the shape of specimens is as important in high strain fatigue studies as it is in static tests, strain concentrating specimens such as notched bars and hour glass shaped specimens should not be used to determine material behavior especially at temperatures and strains that are associated with near perfect placicity. G.G.

Review: This is a good review of the low-cycle fatigue phenomenon. The author appears to be very interested in providing a balanced viewpoint and the associated understanding than he does in promoting one particular point of view. Such a condensed review as this implies that this cannot be the reader's first introduction to low-cycle fatigue. There is little or no discussion of the statistical aspects of scatter, and one presumes then that median life is the life to which reference is being made. This report can be of tutorial benefit to designers and reliability engineers in providing background for their further understanding of low-cycle fatigue; it does not provide direct design information. There are copious references for further reading. It is unusual that one person will take as much time as is necessary to write a review such as this. It deserves wider distribution and needs to be done for many more topics.

R70-15404 ASQC 844; 775

ACOUSTIC EMISSION MONITORING SYSTEM FOR DETECTION OF CRACKS IN A COMPLEX STRUCTURE

Yosio Nakamura (General Dynamics, Fort Worth, Tex.) *American Society for Nondestructive Testing, Spring Conference, Los Angeles, Mar. 9–12, 1970, Paper* 28 p 3 refs

An acoustic emission monitoring system designed to detect, in real time, initiation and growth of cracks in a complex structure during static as well as fatigue testing has been developed. The system consists of arrays of acoustic sensors, logic circuits, and output devices. An effective spatial- and frequency-filter combination permits the use of the system in the presence of the heavy background noise ordinarily encountered in the testing of a large, complex structure. The system is being used successfully in static and fatigue testing of full-scale, as well as small-scale specimens of aircraft components and structures. Author

Review: This is a practical article on the use of acoustic emission for detecting fatigue damage in a test rig. The paper is clearly written and presumes only a little previous knowledge about acoustic emission even in a laboratory test. The article will be of value primarily to those who are doing experimental work in fatigue, although just reading the abstract can show others who are interested in this phenomenon the difficulties in applying it in any practical situation.

R70-15405 ASQC 844

RELIABILITY: EVALUATION FOR TROUBLE-SHOOTING OF HIGH-SPEED TURBOMACHINERY

J. S. Sohre (Professional Engineer and Consultant, 93 Grier Rd., Vernon, Conn.) *American Society of Mechanical Engineers, Petroleum Mechanical Engineering Conference, 1970, Paper* 46 p 13 refs

A procedure is outlined for the systematic evaluation of reliabilities of major components of an installation, as well as of the over-all reliability of the entire unit; it is stated that this approach simplifies the correction of field problems and minimizes total costs. A set of curves is given to coordinate the major factors influencing reliability, such as unit size and type, speed, pressures and temperatures, coupling effects, number of start-stop cycles, starting cycle time, characteristics of supports, foundation, piping, and effects of operating practices and maintenance provisions. Author

Review: This is an unusual paper and is the very antithesis of a highly theoretical one. This paper tries to set down many years of practical experience in a form which can be used as a starting point of where to look for potential trouble in machinery. It is this main thrust of the paper that has been favorably commented upon in the published discussion. The author's numerical system itself does leave something to be desired since a unit with five things in it, each having a reliability factor of 2, would have an overall reliability factor of 32, yet this unit would be more likely to have failures than one which contains just one of the elements and had a reliability factor therefore of only 2. This difficulty could have been overcome if the number 1 were reserved for the highest reliability and the others had less. Nevertheless, if the data are used to provide young engineers, especially, with some ready-made practical experience, it will serve a very valuable purpose in improving the reliability and maintainability of machinery. As the author suggests, each person can modify the curves in light of his own experience; but one is so often in the position of having no quantifiable experience of his own that he needs a few practical numbers. Thus, while the theoretical basis for assigning numbers could have been improved, the basic information is very good.

R70-15406 ASQC 844
THE VALUE OF FAILURE ANALYSIS AS APPLIED TO PLANT ENGINEERING AND MAINTENANCE
Edward G. Nisbett (National Forge Co., Irvine, Pa.) *American Society of Mechanical Engineers, Plant Engineering and Maintenance Conference, Fort Worth, Tex., Mar. 16–18, 1970 Paper* 8 p 4 refs (ASME 70-PEM-8) Avail: $1.00 members; $2.00 nonmembers

It is stated that the intelligent use of metallurgical experience, drawing on failure analysis results, can be effective in reducing plant construction costs and downtime. Attention is drawn to instances where modification of standard practices would have prevented plant outages if the local or general environment had been fully considered. The role of management with regard to utilities and maintenance is discussed against a background of service failure analysis. Author

Review: This article shows that a metallurgist can be of valuable help in determining the cause of failure of many machine parts. Maintenance is cited as the culprit in many unexpected failures, especially maintenance which proceeds by using unsuitable techniques. The author's points are important and well made. The reliability of repaired equipment is no better than its maintenance, and very often the responsibility for maintenance is less when in the hands of those who are not prepared for it. Inadequate funding is probably a major cause of some of the well-meaning but completely inadequate repairs that the author mentions in his example. Having responsible, knowledgeable people paying attention to all the details which could cause failure might be more expensive than paying for the accidents which occasionally occur, but it should be a decision which management makes not by default but after careful study. This article can especially help management to understand the situation.

R70-15410 ASQC 844
FATIGUE-CRACK GROWTH IN PERSPECTIVE
M. R. Gross (Naval Ship Research and Development Lab., Annapolis, Md.) *Naval Engineers Journal,* vol. 82, no. 1 Feb. 1970 p 44–48 3 refs

The similarities between the crack-growth rate [d(2a)/dN] versus stress-intensity range [ΔK] relationship, and the conventional stress [S] versus number of cycles to failure [N] relationship are discussed. The results of published fatigue-crack growth studies are analyzed in terms of broad spectrum fatigue life and limiting conditions. It is concluded that fatigue-crack growth rate is not a simple power function of stress-intensity-factor range as some contend. Furthermore, the scope of fatigue-crack growth studies must be greatly expanded to cover the majority of fatigue failures that occur in service. Author

Review: This is a good paper although it does not fulfill the hopes for it that are easy to get after reading the introduction, i.e., it does not clarify the entire picture for the engineer. But the paper does help put fracture mechanics in a reasonable perspective for one who is quite familiar with practical fatigue curves. The relationships between the ordinary S–N diagram (and associated diagrams) and the qualitative results of fracture mechanics are well explained. The author also quite properly points out that fracture mechanics is not yet an easy tool for designers and other engineers to use because there are a lot of numbers missing from fracture mechanics that practical men will need. It would be nice if a knowledgeable person like the author could write an article every year which would help improve an engineer's perspective on fatigue-crack growth by interpreting the growing literature for him.

R70-15413 ASQC 844
SPOTTING TROUBLE BEFORE IT HAPPENS
John A. Burgess (Westinghouse Electric Corp., Astronuclear Lab., Pittsburgh, Pa.) *Machine Design,* vol. 42, no. 23 Sep. 17, 1970 p 150–155

The techniques of fault tree analysis and failure mode analysis are presented to provide ways to formalize product safety studies. The classes of failure which necessitate the development of a fault tree, and ways in which a product can fail, are described. A sample worksheet illustrates steps involved in failure mode analysis. P.R.F.

Review: This is a good article. It is tutorial and written in simple enough language so that the engineers to whom it is directed can understand it. The fault tree and failure modes analysis are, as the author points out, two different ways of looking at the same thing, viz., failures, their causes and effects. The failure modes effects and criticality analysis as described in the paper are somewhat more comprehensive than the fault tree since it includes more things. It can be extended even further to include estimates of 'cost to eliminate the failure mode or extend the life of the item' and eventually one can wind up with a list showing where is the best place to cure the most troubles with the least money. This kind of analysis, of course, is applicable to any kind of system. This article is recommended to those who have access to it and were not familiar with these two extremely valuable engineering tools for improving the reliability and safety of products. They are a way of organizing the details of knowledge so that their effects are the most visible. They are among the most cost-effective tools available to reliability and design engineers.

R70-15414 ASQC 844
ELECTRICAL RELIABILITY OF PARYLENE FILMS FOR DEVICE PASSIVATION
S. M. Lee, J. J. Licari (North American Rockwell Corp., Autonetics Div., Anaheim, Calif.), and I. Litant (NASA. Electronics Research Center, Cambridge, Mass.) *Metallurgical Transactions,* vol. 1, no. 3 Mar. 1970 p 701–711 9 refs
(Contract NAS 12-2011)
(A70-26395)

Experimental investigation of the applicability of parylene, high-purity and pinhole-free polymeric films as a replacement or an adjunct to inorganic passivation layers or as a barrier coating capable of maintaining the semiconductor surface free of moisture, ions, and other contaminants. The effects of temperature and electrical stress on semiconductor devices coated with various Parylenes were studied using the Rel-chip (which permits determination of immediate and magnified changes in critical electrical device parameters for MOS and IC devices). Changes in the electrical parameters were found to be negligible after the devices were subjected to various stress conditions. The average threshold voltage shifted less than 0.1V, the breakdown voltage changes less than 1V, and the leakage currents drifted within a few picoamperes. A satisfactory technique for applying pinhole-free Parylene coatings is proposed, involving pretreatment of the surface with A-174 silane adhesion promoter, followed by vacuum deposition of Parylene. IAA

Review: This is a good report on new material for passivating semiconductors. There is a continual search for new methods for passivation, both in terms of lower cost and longer, sure life. Even though the tests were accelerated, they lasted only about one week; thus, they should be considered preliminary although most en-

couraging. It is not immediately clear from the paper how easy the film is to apply, most especially how easy it would be to apply during production and the ease with which the film can be inspected nondestructively. The paper is well written (presumably the units which were stressed both electrically and thermally had both the electrical and thermal stresses applied simultaneously), and the experiments appear to have been well conceived and well carried out. Some of the figures are extremely difficult to read due to the very great reduction. It will be interesting to see whether others will experiment with the parylene coatings and, if so, whether it will be applied commercially.

R70-15415 ASQC 844; 782

EFFECT OF NONSTEADY AVIONIC COOLING AIR ENVIRONMENTS ON ELECTRONIC PART RELIABILITY

Donald M. Cawthon (Martin Marietta Corp., Thermodynamics Section, Orlando, Fla.) *In: Proceedings of the Third Annual Seminar on Failure Analysis, University of Pennsylvania, Philadelphia, May 21, 1970* Sponsored by the Institute of Electrical and Electronic Engineers May 1970 p 1–10 9 refs
(Contract NADC N 62269-68-C-0469)
Avail: $5.00

Results of a test program, which subjected sample electronic parts to typical thermal environments of aircraft equipment, are given. The test program identified the key failure-indicating parameters of transistor components and showed that parts operated at constant temperatures even 100 degrees F higher than the maximums for temperature-cycled parts had a life expectancy six or seven times greater than that of the latter. The study indicated the need for more realistic specifications for high-reliability avionic parts and for improved cooling methods. P.R.F.

Review: The title of this paper is somewhat misleading since only one kind of part was tested, namely, a particular power transistor. The conclusions confirm the belief of most reliability engineers that temperature cycling is more detrimental to a part than is operation at a constant high temperature. Those who are familiar with this fact and are satisfied with their information, need not look at the paper; those who are pursuing this phenomenon further will find substantiating data in the paper.

R70-15417 ASQC 844

METALLURGICAL ASPECTS IN FAILED ELECTRICAL AND ELECTRONIC DEVICES

Henry E. Frankel and Alfred J. Babecki (NASA. Goddard Space Flight Center, Greenbelt, Md.) *In: Proceedings of the Third Annual Seminar on Failure Analysis, University of Pennsylvania, Philadelphia, May 21, 1970* Sponsored by the Institute of Electrical and Electronic Engineers May 1970 p 23–32 6 refs
Avail: $5.00

Metallurgical aspects of several component failures, mainly of the non-integrated circuit type, are discussed. Some recommendations are offered for treating the problems of filament evaporation, galvanic corrosion of circuits, poor solder bonds in intermetallics, and high resistance films on electrical connectors. It is noted that these are examples of failures that have arisen on spacecraft programs and are typical of the range of such problems that are inimical to the space program. P.R.F.

Review: This paper illustrates the importance of metallurgical factors in viewing failures of electronic components. Since most electronics engineers have little or no training in metallurgy, it behooves them to have access to professional metallurgists who can aid in the failure analysis. It also behooves them to pick up some of the metallurgical jargon on their own so that they can intelligently converse with these specialists. This paper illustrates the problems quite graphically. Electronics engineers who cannot understand this article need to do reading on the subject.

R70-15418 ASQC 844; 853

SEMICONDUCTOR FAILURE ANALYSIS: SIMULATED TESTING AND CORRECTIVE ACTIONS

E. B. Hakim (Army Electronics Command, Electronic Components Lab., Fort Monmouth, N. J.) *In: Proceedings of the Third Annual Seminar on Failure Analysis, University of Pennsylvania, Philadelphia, May 21, 1970* Sponsored by the Institute of Electrical and Electronic Engineers May 1970 p 41–46 3 refs
Avail: $5.00

The various techniques used to study failure modes in radio frequencies power transistors are described: failure analysis using an electron microprobe; visible light emission produced by microplasmas and mesoplasmas; and an attempted correlation between the amount of microplasma emission or junction breakdown uniformity and operational reliability. It has been found, however, that infrared scanning using a high resolution radiometer makes possible actual operational device thermal ratings. This procedure permits the calculation of hot-spot thermal resistance which is much more pessimistic than conventional thermal resistance measurements, but allows a more accurate prediction of device reliability. P.R.F.

Review: The more things change, the more they stay the same. One very good message that comes through from this paper is that when devices fail, find out what is really going on—as opposed to what someone says is going on. This has been the maxim in electronics for over a quarter of a century and was probably invented by the Greeks (but it needs repeating, just the same). The author has reported on some very good work on finding out just what was going on in these RF power transistors, and the results obtained with radiometers are important. It shows that the whole concept of thermal resistance is not as simple as it is often thought to be, and further that the manufacturer (however innocently) is not necessarily a good guide at all as to what the thermal resistance is. This paper is recommended reading for all reliability and electronic design engineers.

R70-15419 ASQC 844; 782

AMBIENT EFFECTS ON GOLD-ALUMINUM BONDS

Thomas J. Rossiter (Rome Air Development Center, Griffiss AFB, N. Y.) *In: Proceedings of the Third Annual Seminar on Failure Analysis, University of Pennsylvania, Philadelphia, May 21, 1970* Sponsored by the Institute of Electrical and Electronic Engineers May 1970 p 47–52 5 refs
Avail: $5.00

The effect of ambient on the life of gold-aluminum thermocompression bonds was investigated. Mass spectrometry techniques were used to gas analyze both degraded and unstressed samples in an effort to determine the gas which causes the severe bond degradation. Three important results were observed: first, ambient was found to have a greater effect on the life of gold-aluminum bonds than any other parameter previously studied; second, the two major types of voiding which have been reported for many years were found to be related through ambient; and third, the ambient which seems to cause this effect is oxygen. It

was noted that the absence of oxygen results in early bond failure and the presence of oxygen significantly extends the life of gold-aluminum bonds. P.R.F.

Review: Gold-aluminum bond failure must be one of the best documented failures in electronics. Intermetallic compound formation, Kirkendall effect, and purple plague have become familiar terms to reliability engineers studying the failures to which silicon circuits are prone. For at least seven years now (1970), the properties of the gold-aluminum bond have been examined under a wide range of temperature and anticipated operating conditions. The intuitive feeling of outsiders to these specialized investigations is that there are likely to be few surprises concerning this particular bonding system from here on in. This paper will jolt such thinking. In it, the author identifies a dependence hithertofore not recognized—at least in the open literature—and yet clearly of major significance. Rossiter's work shows the influence of oxygen upon the ageing properties of gold-aluminum bonds, which comes as something of a shock because so basic a dependence for such a thoroughly-studied metallurgical system should not be appearing in the literature for the first time in 1970. The physics and chemistry are not adequately developed but the data presented here demand answers, further work, and fuller understanding. This paper or its equivalent message is of first-order importance to silicon technologists. Many will wonder how such a correlation could have escaped recognition for so long.

R70-15420 ASQC 844

CURRENT CONCEPTS IN FAILURE ANALYSIS

David B. Christian (Xerox Corp., Rochester, N. Y.) *In: Proceedings of the Third Annual Seminar on Failure Analysis, University of Pennsylvania, Philadelphia, May 21, 1970* Sponsored by the Institute of Electrical and Electronic Engineers May 1970 p 55–60
Avail: $5.00

The nature and causes of failure are described as a prelude to understanding the methods of failure analysis. Three reasons are given for failure: poor design, design misapplication, and manufacturing process variations. Statistical failure distributions of random variables are discussed with graphs indicating that components do not always fail with a constant failure rate. The methods of failure analysis are then given: 1) verification of the failure mode and correlation to the failure cause; 2) demonstration of the failure cause and a statistical measure of its intensity; and 3) evaluation of proposed corrective actions which must demonstrate the solution of the problem with appropriate statistical measures to verify that there will be an economic gain with the solution. The point is made, in the discussion on new directions for failure analysis, that techniques should be developed which evaluate designs and processes before failure occurs. P.R.F.

Review: There is a great deal of good material in this paper (some of which the author has presented before). A very important message is that if people would just do as well as they now know how (and have known for many years), there would be many fewer failures. The author's comment that one of the best failure prevention techniques is to make the quality level visible to the supplier is good. The discussion of distributions (page 58) is not necessary to the main thrust of the paper and is not as good as the rest of the paper; for example, the statement "the principal interest to us is that any homogeneous distribution plots as a straight line on Weibull probability paper" can only be a definition of a homogeneous distribution. A Gaussian distribution is not a special case of the Weibull distribution; not every Gaussian distribution can be approximated by a Weibull one, but Weibull distributions with shape parameter approximately 3.5 are very close to being Gaussian. (For the two-parameter Weibull distribution, the coefficient of variation, σ/μ, must be about 1/3 when the distribution approximates a Gaussian distribution. The σ/μ in a two-parameter Weibull distribution depends only on the shape parameter, not on the scale parameter; whereas for the Gaussian distribution σ/μ can have any positive value—although $\sigma/\mu << 1$ is usually desirable for high reliability.) The author's law number 2 (page 58) is not always correct. Fatigue in steel parts is an excellent example where the scatter in lifetimes is much less (even on a percentage basis) at high stresses than it is at low stresses—this is especially true in the range in which steels are often applied (lives of 10^4 or more cycles). Much of the paper gives good practical advice. It does not use incomprehensible jargon and is plainly enough stated so that anyone can get the message.

R70-15421 ASQC 844

A SURVEY OF FAILURE ANALYSIS TECHNIQUES FOR INTEGRATED CIRCUITS

S. Silverman and A. C. Woodside (IBM Corp., Components Div., Burlington, Vt.) *In: Proceedings of the Third Annual Seminar on Failure Analysis, University of Pennsylvania, Philadelphia, May 21, 1970* Sponsored by the Institute of Electrical and Electronic Engineers May 1970 p 67–74
Avail: $5.00

Techniques and philosophies of failure analysis are discussed. Several failure modes and some failure mechanisms are addressed, and the techniques used to analyze these failures are defined. Development of new failure analysis techniques is shown to be an important part of the job as this enables failure analysis to keep abreast of the changing technologies. Author

Review: The discussion of failure analysis techniques presented in this paper is broad and necessarily shallow. The authors state that their intent is "to broaden the information exchange by sharing with you some of our failure analysis techniques as well as our problems. The paper is formulated to give valuable information to the experienced and inexperienced failure analyst." Unfortunately, the paper fails to deliver. Communication is a problem. To many readers, an integrated circuit is a multi-element silicon chip hermetically sealed in a flat pack. The authors are not talking about this type of construction but rather about a modular construction, possibly unique to IBM's SLT but, at any rate, not pictured or described in the paper. The visual analysis and chip removal techniques make sense only with the housing or mounting the authors have in mind. When to remove a chip mechanically and when to remove it chemically is not amplified beyond, "The method of removal depends on the type of failure." Many tools and techniques are mentioned; the listing is complete and up to date. Knowing when to use these tools is still a matter of common sense and intuition, however; this paper offers no optimum procedure for rapidly and efficiently zeroing in on cause of failure in spite of the hints that failure analysis is now a science. The development of new failure analysis techniques is no doubt highly desirable, as the authors state in several places, but the paper fails to communicate the urgency of this statement or amplify the details. It can be accepted in the same sense as such platitudes as "progress is important" or "failure analysts should do the best job they can."

R70-15423 ASQC 844

RELIABILITY OF REACTOR SAFETY SYSTEMS

F. C. Olds (Senior Ed.) *Power Engineering*, vol. 74 Jan. 1970 p 46–49

The point is made that the nuclear power industry could achieve mean-time-between-failures of thousands of years for a given safety system. The use of computers programmed to test constantly thousands of selected points, already utilized by the aerospace industry, is recommended as a possible way to insure the reliability of reactor safety systems. Instantaneous fault detection by computer analysis combined with the right type of redundancy is seen to result in a mean-time-to-repair which consists of only the time it takes to identify, walk over, and make the repair. When immediate replacement of the channel or component can take place, MTTR can be made sufficiently small that the overall safety system can never fail. P.R.F.

Review: This is an interesting article to read for several reasons. First of all, it compares the nuclear power industry with the aerospace industry, and second, it is in the form of an interview in which points of view tend to be expressed more pointedly than in a traditional article. It has the disadvantages that the author has little control over what is printed and that the tremendous condensation prevents elaboration on difficult points. (In a private communication the author has pointed out " . . . the obvious fact that in this article I am selling something and clearly it is not good sales technique to elaborately point out all of the problems with my product.") Most of the points made are very good ones. Many people who make aerospace reliability calculations wish they were as sure of them as Professor Schultz seems to be. Failure probabilities on the order of 10^{-4} are likely to be uncertain within a factor of 5, for example, and generic failure rates (those dealing with a type of component only) in military handbooks are lucky to be accurate within a factor of 10 for any particular batch you may buy. The benefits of redundancy presume statistical independence of the failures and insofar as an aggravating environment is uncertain, the failures are not statistically independent. The use of computers in automatic checkout (both testing and checking in the author's terminology) should be investigated but it is very definitely not just a simple matter of hooking up a computer to the system and letting it go to work. A tremendous amount of electrical engineering and programming are involved. There are other controversial elements in the paper, although such controversy is probably healthy for such a young industry which is as staid as the author claims. To get things done, one often needs to shake people up.

R70-15424 ASQC 844

LOAD RATINGS AND FATIGUE LIFE PREDICTION FOR BALL AND ROLLER BEARINGS

J. I. McCool (SKF Industires, Inc., Research and Engineering Center, King of Prussia, Pa.) *(American Society of Mechanical Engineers, Lubrication Symposium, San Francisco, Jun. 16–19, 1969.) Transactions of the* ASME, Series F, vol. 92, no. 1 Jan. 1970 p 16–22 11 refs

(Contract RADC F 30602-68-C-0147)

A review of current rolling bearing load rating and life prediction practices is given, based on the ASA standard method. Experimental results show the existence of life-factors in addition to those encompassed in the ASA standard. A more general rolling contact fatigue theory is sketched but is not yet at a stage where it can be applied to practical life calculations. Therefore a simple generalization of ASA life formulas is proposed for practical use, which accounts for material and environmental variables by multiplicative factors and permits life prediction for any desired reliability using another, tabulated factor. Author

Review: This is an interesting paper especially because of the discussions and author's rebuttal at the end. In the author's rebuttal, he states that the main purpose of the paper was to stimulate discussion on an important topic. This is not necessarily clear from the paper wherein he seems to be very seriously putting forth certain ideas for their own sake rather than just to stimulate discussion. The compromises and tradeoffs necessary for a standardized rating system are made very clear by the paper and the discussion. If you get accuracy of representation, you tend to lose tractability; and standardization becomes difficult. This is true in almost all fields, expecially those involving mechanical power transmission. One difficulty which is touched upon in the body of the paper but not dwelled on at length is the position the customer finds himself in. All he knows is that he has bought some bearings that presumably met certain standards, at least on the average. He has no way of knowing how large or small a group he must buy in order to be "on the average" nor how well the manufacturer has met his obligations in providing components which meet the standard. Since the ratings involve probabilistic considerations, obviously sampling errors can be and often are important. (This is especially true when one tries to make extrapolations out into the tails of a probability distribution when most of the data were generated near the central portion of the distribution.) Generally speaking, in order to have standardization work at all for the great majority of designers and users, accuracy of representation must be sacrificed for tractability, especially since customers do not ordinarily inspect a manufacturer's premises nor check his quality control and manufacturing procedures. This paper can be read profitably by reliability engineers and designers who wish to become fully informed. It is not recommended for those who do not care to be confused by more facts. In a private communication, the author has stated that the Antifriction Bearing Manufacturer's Association (AFBMA) have recognized the points made in the paper and are presently considering a revision to the industry rating standards.

R70-15427 ASQC 844; 782

LOADING TRANSFORMERS ACCORDING TO TEMPERATURE

B. W. Estlin (British Columbia Hydro, Canada) *Electrical Review*, vol. 186, no. 9 27 Feb. 1970 p 321-323 2 refs

A recent survey of British electricity supply industry practice has indicated that loading transformers to hot spot temperature limits offers scope for selective increases of up to 15 percent in transformer cyclic ratings with no reduction in transformer normal life. Author

Review: It is helpful to reliability engineers to see how people in other fields handle the same kinds of problems that are treated by electronics-reliability. In this case, it is the aging of dielectrics and it is power-electrical engineers who are publishing their viewpoint. Perhaps the three most important ideas (for reliability engineers) to be gleaned from this paper are: (1) Arrhenius behavior is presumed for the dielectric, (2) the activation energy is presumed to be about 1.3 electron volts, a rather high value compared to most activation energies encountered in reliability engineering, and (3) the scatter in life is apparently presumed to be negligible since it is not mentioned at all. The main point of the paper for power engineers is that most of the aging occurs at high temperature portions of a transformer's life and that it may be economical to run these temperatures up to a safe limit of a 140°C (hot spot temperature). A nominal overloading of power transformers (insofar as insulation life is concerned) is often considered to be an economic type of operation. Presumably the electrical performance of the transformer is not compromised appreciably.

Some papers have treated the problem of the life of a power transformer insulation at different temperatures in a much more sophisticated fashion by considering the very transient nature of the temperature behavior. Whether the accuracy of the original data justifies the increased sophistication is not known by this reviewer.

R70-15428 ASQC 844; 824

FATIGUE AND CYCLIC THERMAL SOFTENING OF THERMOPLASTICS

I. Constable, J. G. Williams (Imperial College of Science and Technology, Dept. of Mechanical Engineering, London, England) and D. J. Burns (Waterloo University, Dept. of Mechanical Engineering, Ontario, Canada) *Journal of Mechanical Engineering Science*, vol. 12, no. 1 1970 p 20–29 9 refs

Cyclic thermal softening in thermoplastic components is quantitatively related to loss compliance, specimen geometry, and the frequency and magnitude of the cyclic load. The results of cyclic bending tests on polymethylmethacrylate and polyvinylchloride beams of rectangular and circular cross-section are analyzed. For the service conditions considered, the polymethylmethacrylate specimens showed both failure modes of distortion and fracture, whereas the polyvinylchloride specimens failed as a result of fatigue crack propagation. P.R.F.

Review: The failure mechanisms in plastics are somewhat different from those in structural metals. This paper discusses some of those differences, and in particular gives experimental data on thermal softening due to the mechanical hysteresis as losses in fatigue. Both the theory and the data will be of direct use to designers and reliability engineers although the data are very limited. In ordinary cyclic fatigue, no mention is made of differences due to cycling rate. In the thermal softening, there is, of course, a rate effect explicitly considered. In the derivation, it is assumed that the stress is sinusoidal everywhere. Since it is the overall strain that is usually applied in a sinusoidal fashion, it must be presumed that no significant errors occur due to this approximation (for example, higher order harmonics generated by the non-linearity would be negligible). The authors have extended the theory of cyclic thermal softening for plastics in a form that will generally by useable by design engineers although not all of the necessary data for use in the formula will always be readily available. As more and more plastics are used to replace metals, knowledge of how the plastics behave is of increasing importance to the reliability of the structure.

R70-15431 ASQC 844

HOW METALS BREAK

A. Strang (GEC Power Engineering, Central Metallurgical Lab, Whetstone, Leicester, England) *Science Journal*, vol. 6, no. 2 Feb. 1970 p 34–40

Fracture mechanisms are discussed in terms of a metal's fracture surface. The scanning electron microscope and the optical microscope are used to study the fracture surface to determine the fracture path and its relationship to other microstructural features which may be present. P.R.F.

Review: This article appeared in a journal for a general audience as opposed to one for those with specific metallurgical backgrounds and thus perhaps some of the looseness can be forgiven. It is generally a good article and discusses some of the failure modes of metals and introduces the fracture surface as providing important clues to the kind of failure that has been experienced. The biggest difficulty is the implicit assumption that strength has a single dimension and the lack of distinction sometimes between nominal and actual stress. Obviously, the author is competent to discuss these matters. The difficulties arise in trying to translate metallurgical jargon into language that is understandable to the layman and acceptable to the metallurgist. Reliability engineers who are not familiar with the material in this paper should make it a point to read papers of this type which give an introduction to metal failure. No mention is made of crack propagation. An elementary article which does treat fracture mechanics is the one by Shannon and Brown which is reviewed in this issue of RATR.

R70-15432 ASQC 844

PROGRESS IN FRACTURE MECHANICS

John L. Shannon, Jr. and William F. Brown, Jr. (NASA, Lewis Research Center, Cleveland, Ohio) *Machine Design*, vol. 42 Mar. 5, 1970 p 133–139 7 refs

(A70-23799)

Discussion of advances in the newly developed discipline of fracture mechanics which has now matured into a key branch of stress analysis and structural design. It is pointed out that structures can fail by plastic deformation and by brittle fracture. The wreckage of a 260-in. rocket motor case is considered as an example of failure by brittle fracture. Essential features of brittle fracture are examined and an evaluation of fracture toughness is conducted. Methods for measuring fracture toughness are considered and the application of fracture mechanics is discussed. IAA

Review: This is a good paper on fracture mechanics. It is written in terms that the ordinary mechanical engineer can understand and shows quite clearly that there is much more to the real strength of a material than its tensile or yield strength. The "strength reducing" factors are explained well; reliability and design engineers should be familiar with the concepts in this paper. The concepts emphasize the fact that strength of a material is not a single quantity but has many dimensions. The theory and practice of fracture mechanics is not yet advanced enough that it is useable for direct calculations by the design engineer in most phases of his work. But, as the authors point out, it can provide a great deal of guidance and direction for the engineer. Reliability engineers should be familiar with this type of elementary introduction to fracture mechanics.

R70-15434 ASQC 844

PRODUCT RISKS: PREDICTION TECHNIQUES

Paul Gottfried (Booz, Allen Applied Research, Inc., Bethesda, Md.) *In: Proceedings of the 1970 Product Liability Prevention Conference, Newark, N. J., Aug. 26–28, 1970* Sponsored by American Society for Quality Control, American Society of Safety Engineers, Institute of Electrical and Electronic Engineers, and Newark College of Engineering American Society for Quality Control, Inc. 1970 p 3–14 3 refs

Prediction techniques devised in connection with reliability and safety analysis of military and space systems which can be brought to bear on commercial/industrial problems are outlined. Emphasis is placed on the need for explicit definition of malfunction consequences, on problems in data acquisition, and on the requirement for multi-disciplinary analysis arising from the non-technical ramifications of product liability. Author

Review: This is a good paper. The amount of mathematics in it is small and can safely be disregarded by those who wish to. The

major points are engineering ones as is proper in a discussion of reliability and safety. The fault tree and failure modes and effects analyses are properly emphasized. The author's preference for the fault tree is not shared by all, but, as he points out, the two are logically equivalent. In practice, of course, one does not begin the failure modes and effects analysis with raw materials but rather with component parts and he has as his option how small a subsystem he wishes to choose for these component parts. Again, in practice, most engineers will work frontwards and backwards anyway to make sure that they have a complete table. Whichever way one does it, it is one of the most effective tasks that can be performed as part of a reliability and safety effort. People might also argue on which has the best physical basis—the Weibull distribution or the lognormal. Obviously, a relatively simple model exists for each. It is also true that for many ordinary-sized samples, it is impossible to distinguish between the two for any given set of data. Managers and others who are not familiar with technical jargon and sophisticated mathematics can read most of this paper with ease, and the parts that they must skip over will not hurt them.

R70-15438 ASQC 844; 775

VIBRATION-PROTECTION SYSTEMS USING VIBRATION TO FORECAST MACHINE FAILURE

Wayne Tustin (Tustin Institute of Technology Inc., Santa Barbara, Calif.) *Machine Design,* vol. 42, no. 2 1 Oct. 1970 p 102–106

Vibration detection and protection systems are described. The systems continuously monitor vibration and sound an alarm when it unduly increases, thereby warning that trouble is coming while repairs are still minor. Vibration sensors, ranging from simple levers and switches to complex accelerometers, are discussed. It is noted that the quality of protection is directly related to the price of the system. Methods of installing a sensor system and determining the vibration level at which it should trip are analyzed. P.R.F.

Review: High reliability in a system is often achieved by sensing an impending failure and shutting the system down for corrective maintenance before the failure has actually occurred. In many situations, this prevents an accident and minimizes secondary damage. This paper deals with one such situation, namely, shutting a system down before the vibration becomes excessive. It is a good article; there is a minimum of technical jargon; design and reliability engineers will be able to understand it easily. The illustrations range all the way from an extremely simple device used in an automatic washing machine to rather complex and expensive devices for protecting very high investments. The paper is recommended reading for those who are not otherwise familiar with the points the author is making.

85 DEMONSTRATION/MEASUREMENT

R70-15387 ASQC 851; 844

Battelle Memorial Inst, Columbus, Ohio. Columbus Labs.

STUDY OF SPACE BATTERY ACCELERATED TESTING TECHNIQUES. PHASE 2 REPORT: IDEAL APPROACHES TOWARDS ACCELERATED TESTS AND ANALYSIS OF DATA

R. E. Thomas, E. W. Brooman, J. H. Waite, O. L. Linebrink, and J. McCallum Aug. 1969 118 p refs

(Contract NAS5-11594)

(N70-12478; NASA-CR-107114) Avail: CFSTI

The object of this program is to develop testing procedures to accelerate the aging of electrochemical cells and batteries so that the equivalent of years of data may be acquired in significantly less time to enable a valid prediction of cell life. In this phase, empirical, statistical, and physical concepts are applied to the design of an ideal accelerated test. Empirical methods of analysis, such as the Automatic Interaction Detector Program, are proposed to search for precursors of failure; statistical methods, such as response surfaces, are proposed for assessing statistical validity and predicting parametric failures during the test; and physical methods based on stress strain laws are proposed for obtaining an understanding of physical mechanisms associated with the degradation of cells with time. Six kinds of stresses are identified in the development of the physical approach to accelerated testing: (1) pressure gradients, (2) voltage gradients, (3) temperature gradients, (4) concentration gradients, (5) velocity gradients (vibrations), and (6) frequency gradients (electromagnetic absorption). Each stress has associated with it a corresponding flux that is identified as a rate of strain. Static strains are also identified for the first four stresses itemized above. Author

Review: This is an interesting, constructive, worthwhile paper. It is interesting because it brings some new insights to the subject. It is constructive because it expounds in an appropriately understandable manner several useful ways of looking at and analyzing data. The fresh insights, the exposition of ways of analyzing data, and the physical intuition ought to advance the state of the art of accelerated testing. The material is not at all limited to spacecraft batteries although they are used as the examples. Both the authors and the contractors are to be commended for this report. The introduction of linear constitutive equations is not as new and original as the authors seem to claim. The principles are known and applied in theoretical thermodynamics (indeed, thermodynamics has advanced much further than that). In general, one tries to define parameters which are reasonably constant over rather wide ranges of the variables for some material. As the authors have shown, if the ratio of potential gradient to strain rate is a constant, then the electrical material is an "Ohm's Law" resistor; if the ratio of potential gradient to strain is constant, then the electrical material is a perfect capacitor. The mechanical analogies are a viscous fluid and an elastic solid. The search is always on for various pairs of conjugate variables whose ratio, at least for some materials, is relatively constant. In the statistical analysis, even though the authors were quite careful in their description, it must be emphasized again and again that a brute force estimation of parameters (such as orthogonal polynomials should never be used for extrapolation. Ordinarily, the better the fit is inside the range of the data, the worse will be the fit outside the range. The development of physical understanding deals largely with gradients; for example, electrical potential gradients. However, some damagers such as temperature can operate without a corresponding gradient in the material of concern. Furthermore, not all "stresses" as defined will necessarily decrease the quality faster when they are increased; for example, coaxing in fatigue, annealing in metals, and freezing of aluminum electrolytic capacitors. In other words, increasing the stress level does not always increase the severity level, especially when *stress* is used in the very general sense. Regardless of the comments in the above three paragraphs, and regardless of the fact that much engineering judgment was used in some of the descriptions and analysis, this report should be read and carefully considered by everyone who is involved with accelerated testing of any kind of

component. It should, of course, be read critically (as with most any document). The quantity of new insights per page in this report is well above the average.

R70-15398 ASQC 851

LOAD-LIFE MATRIX TESTING OF REED SWITCH CAPSULES: AN INDUSTRY STANDARD APPROACH

B. C. Stickley and E. G. Tutle (General Electric Co., Waynesboro, Va.) *Oklahoma State University and the National Association of Relay Manufacturers, Annual National Relay Conference, 18th, Oklahoma State University, Stillwater, Okla., Apr. 28–29, 1970 Proceedings* Scottsdale, Ariz. National Association of Relay Manufacturers 1970 p 17-1 to 17-10 7 refs

Avail: $5.00

Results are presented of an experimental test program designed to assess the switching capability of reed switch capsules over several decades of currents and voltages. It was found that similarly rated reed capsules from different manufacturers will not necessarily exhibit identical performance. Test data also indicate that load life matrix testing can be a valuable quality control tool, and that long-term performance can be predicted by short-term matrix testing. Suggestions are offered for the standardization of matrix testing to evaluate reed switches reasonably and economically and to determine lot performance. P.R.F.

Review: Here we find a component which is relatively inexpensive and wherein life testing can be accelerated often by merely increasing the rate at which it accumulates cycles. The authors make some very good points about optimum conditions for operating these switches and the fact that a matrix type of test is helpful in determining these optimum conditions as well as predicting life at less than optimum conditions. Unfortunately for the industry as a whole, the authors mention that the switches of different manufacturers seem to behave differently in regard to the optimum operating regions and that the optimum operating region is also expected to change as a function of temperature. Thus, these tests depart from the simple two-dimensional matrix and become a three- or four-dimensional array: load voltage, load current, manufacturer, and operating temperature. Perhaps, as the authors are suggesting, if the industry could arrive at suitable standard behavior of load life as a function of the parameters, then testing by individual companies (whether consumers or manufacturers could be considerably simplified. The paper is worth reading by reliability engineers and manufacturers of reed switches. It is unlikely that the exact form specified by the authors would eventually be adopted, but it serves as a very good first-cut.

SUBJECT INDEX

Typical Subject Index Listing

PROBABILITY
Procedures for applying sequential probability ratio tests in analyzing checkout and support equipment
TR-3 c84 R70-12733

SUBJECT TERM | REPORT NUMBER | NOTATION OF CONTENT | CATEGORY NUMBER | *RATR* ACCESSION NUMBER

The Notation of Content, rather than the title, is used to provide a more exact description of the subject matter. The category number and *RATR* accession number are used to locate the abstract-review appearing in the abstract section of *RATR*.

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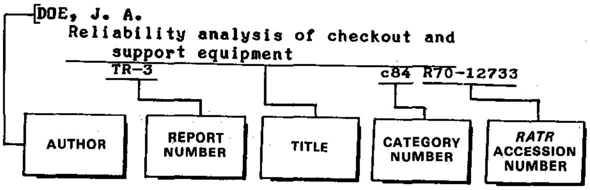
PERSONAL AUTHOR INDEX

Typical Personal Author Index Listing



The category number and the *RATR* accession number are used to locate the abstract-review appearing in the abstract section of *RATR*.

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REPORT AND CODE INDEX

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS VOLUME 10 NUMBER 12

List of Report Numbers

This may be used to identify the *RATR* accession number of reports covered in this journal. To the right of each report number is the *RATR* accession number preceded by the category number for locating the abstract-review in the abstract section of *RATR*. For purposes of this index, AD, N, and A numbers (accession numbers from *TAB, STAR,* and *IAA,* respectively) and ASQC code numbers are treated as "report" numbers. Thus, the section of this index listing ASQC codes may be used to identify the *RATR* accession number of the coded abstract-reviews appearing in *RATR*.

ACCESSION NUMBER INDEX

List of *RATR* Accession Numbers

This list of *RATR* accession numbers may be used to identify the category in which a numbered abstract-review appears in the abstract section of this journal. Accession numbers are arranged in ascending order. Preceding each accession number is the category number for locating the abstract-review in the abstract section of *RATR*.

NASA-Langley, 1970

SPECIAL NOTICE INSIDE

Reliability Abstracts and Technical Reviews

JANUARY–DECEMBER 1970

Volume 10
Numbers 1–12

R70-14805—R70-15438

ANNUAL INDEX

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

SPECIAL NOTICE

Budget and personnel stringencies make it necessary for NASA to discontinue *Reliability Abstracts and Technical Reviews (RATR)* at the end of the calendar year.

Publication of *RATR* will cease with this issuance of the Annual Index for January–December 1970.

There are no plans to institute any similar-type publication.

Reliability and Quality Assurance Office
National Aeronautics and Space Administration

Table of Contents

Volume 10 Numbers 1–12 / January–December 1970

ANNUAL INDEX

The Contents of
Reliability Abstracts and Technical Reviews
ANNUAL INDEX

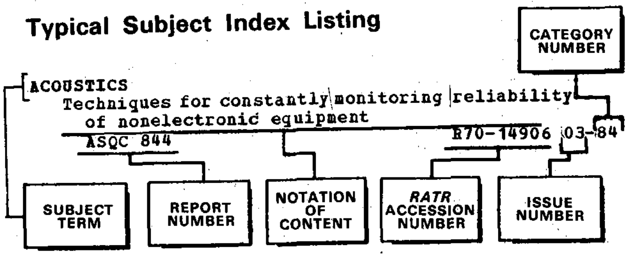
This Annual Index is an edited consolidation of the indexes to the individual issues of *Reliability Abstracts and Technical Reviews* for the calendar year 1970 (Volume 10, Numbers 1 through 12). There are four cumulations in this Annual Index. The Subject Index is to assist in scanning or searching the literature on specific topics. The Personal Author Index identifies the publications of specific authors. The Report and Code Index is a listing of the report numbers of items abstracted and reviewed; this index also includes a listing of the American Society for Quality Control codes for identifying the *RATR* accession numbers of items to which the codes have been assigned. A complete listing of these codes appears on the inside back cover of the Annual Index. The Accession Number Index identifies the issues and the categories in which the abstract-reviews appear in Volume 10.

Each entry in this index includes an accession number, e.g., R70-12345, a unique identification number assigned to each abstract-review that was indexed and announced in *RATR* during the year. In addition to the accession number, each entry in the Annual Index includes a 4-digit number (e.g., 10-84). The first two digits identify the issue of *RATR* in which the abstract-review is located. The two digits after the hyphen identify the ASQC category code assigned to the abstract-review.

SUBJECT INDEX

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS VOLUME 10 NUMBERS 1-12

Typical Subject Index Listing



The Notation of Content, rather than the title, is used to provide a more exact description of the subject matter. The *RATR* accession number, the issue number, and the category number are used to locate the abstract-review in the abstract section of an issue of *RATR*. The first two digits following the accession number identify the issue of *RATR*, and the two digits after the hyphen identify the category in which the abstract-review appears.

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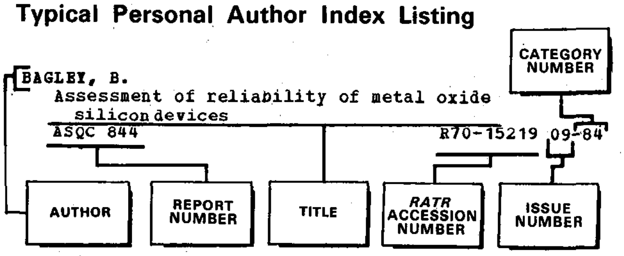
PERSONAL AUTHOR INDEX

Typical Personal Author Index Listing



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REPORT AND CODE INDEX

RELIABILITY ABSTRACTS AND TECHNICAL REVIEWS VOLUME 10 NUMBERS 1-12

List of Report Numbers

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ACCESSION NUMBER INDEX

List of *RATR* Accession Numbers

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